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NOTES ON THE HISTORY OF THE SCOTTISH MOUNTAIN BLACKFACE SHEEP AND SOME GENETICAL OBSERVATIONS ON CERTAIN BREED CHARACTERISTICS[1]

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INTRODUCTION

The Scottish Mountain Blackface Sheep is the most numerous breed in the British Isles, and a few flocks have been established in other countries, including Canada, the United States (where they were first introduced in 1861 (30)), South America, Italy and Japan.

The name of the breed is in part misleading, for while Scotland is now its main home and it is a mountain sheep, only a small percentage of the breed have completely black faces; in fact, the face colour may vary from solid black to over four-fifths white.

The breeding and management of a typical Blackface flock is less controlled than almost any other British breed of domesticated sheep. They graze upon natural hill pasturages, consisting of heather, grass and rock plants, uninfluenced by manuring, sowing or cultivation, with the exception of heather burning, bracken cutting or open draining. Typical hills generally carry one ewe for every one to three acres.

The flock, from which much of the data recorded at the end of this paper was obtained, grazed land varying from 350 to 3,400 feet above sea level and was managed like other flocks in the district, except that the provision of extra fencing on the low ground allowed more careful mating than is generally possible; therefore, the year to year variations in conditions were uncontrolled but were similar for the whole flock.

HISTORY

The history of the breed is shrouded in obscurity, and while the lack of recorded facts is more than counterbalanced by the number of theories, plausible and otherwise, there are sufficient recorded facts to account for some of the present local variations in the breed, and to account for prejudices held by flockmasters and shepherds against certain types.

Ewart (23) traces both the Merino and Blackface to *Ovis ammon*, but Pease (46) believes that the ancestry of the Blackface can be traced from the Bharal, through the various forms of *Ovis vignei* to the domesticated Barwal of Central Asia, and thence to the so-called Danish Heath

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sheep—a black faced, black legged, horned sheep from which such related breeds as the Old Norfolk, Old Sussex, Old Berkshire, Old Hampshire and Old Shropshire and their modern derivatives have descended. In this theory stress is laid on the Roman nose and behaviour in the hills of the wild ancestors.

The Armada of 1588, according to some writers (5, 61), played its part in establishing the Blackface breed. Sheep from wrecked galleons are reputed to have been crossed with a dun faced native breed. The fact that sheep with fleeces similar to that of Blackfaces are found in the north-west Pyrenees is given as evidence; however, it is easier to believe that both breeds have been derived from similar stock, such as the Old European Black Legged Heath sheep.

There is evidence that for many centuries a breed or breeds of sheep of the Old Heath type were firmly established in central England, and that they spread north via the Pennine Chain. Hector Boathius, writing about 1460 (31, 32), stated that Blackfaces were then the only type of sheep in the vale of the Esk. If this is correct it refutes the belief that James IV imported the first flock to Ettrick in 1503 (5, 29, 31, 40, 62). Ettrick certainly seems to have been the focus from which the breed later spread to Tweeddale and Lammermuir, where by the middle of the eighteenth century, their origin had been almost forgotten. Yet it was only about that time that Blackfaces spread via Ayrshire into Argyllshire and into Dumbartonshire and Perthshire (34, 40, 61). About 1775 they were imported into Rossshire (33).

It is more than probable that the sheep with which the Blackfaces interbred when they spread to new districts even now show their influence, especially in unhealthy localities, such as some parts of the west coast; there the importation of young rams is difficult and the importation of young females almost impossible. This has necessitated a high value being placed on stock acclimatized to the ground. Undoubtedly some of the inferior characteristics of these native sheep have persisted in the progeny of the Blackfaces, and account for some of the present day dislike for signs of the cross, such as a dun-coloured tinge on the face, although the origin of the prejudice may have been forgotten. That the native sheep were inferior is suggested by the quick spread of the Blackfaces in the latter half of the eighteenth century, even allowing for the fact that economic conditions were an important factor.

Probably the native sheep were most numerous near the coast, since the dun faced breed was described as too delicate for the mountains, and even at the present day Blackfaces from the west tend to be inferior to those from farther inland, an inferiority not completely accounted for by economic and health conditions. In the central Highlands, cattle were definitely of greater importance than sheep, but there is evidence, circumstantial and otherwise, that there were some native sheep there, for complaints were made that the Blackfaces were debasing the indigenous breed. Moreover, since, even in Yorkshire (38), Blackfaces did not produce twins without flushing in 1788, they could not have spread as rapidly as they did without some stock being already there as a foundation, even allowing for the fact that the wethers were kept until they were 3 to 5 years old and many young wethers were brought north to graze for 3 or

Showing places mentioned in text.

4 years. All the evidence shows that the hardiness of the Blackfaces was the main factor which allowed the rapid spread of the breed, in spite of much local prejudice.

When Blackfaces spread to Perthshire they may have interbred with another Blackface type, the Lomond Hill sheep (40). But elsewhere the native sheep were undoubtedly white or dun faced, with a soft wool; whether they constituted one or two or more breeds is doubtful (56), some writers described them as dun faced (15, 62), others as white faced (5, 61), and others as either (34). Unbiased testimony is given by Daniel,

who in 1813 (6), illustrating a tour along the west coast of England, Wales and Scotland, includes in his pictures polled white faced sheep from the Solway to the Outer Hebrides, with the exception of one picture of Harris, which shows some sheep coloured in both face and body, in addition to white sheep.

PRESENT DISTRIBUTION

In 1915 there were four million Blackfaces (34), and in 1932 they were 7 times more numerous than Cheviots (56), the other chief mountain breed in Scotland.

At present, on the mainland in Scotland, Blackface flocks are common as far north as latitude 57° 50, (i.e. Loch Broom to Bonar Bridge). When they first extended north they reached Caithness, but now except for an occasional isolated flock, they have been displaced north of latitude 57° 50 by the Sutherland Cheviot, especially on the grassy hills. In the counties of Inverness, Argyll, Perth, Angus and Dumbarton, it is the principal mountain breed; they are also common in Rossshire and the Western Islands. South of the River Forth the breed is firmly established throughout the Uplands. Most of the finest specimens are bred in Lanarkshire and in certain parts of the contiguous countries; the upper parts of the Tweed basin, the Lammermuirs, Dumfriesshire and parts of Ayrshire all produce a well-built hardy type. There are many flocks in Kirkcudbrightshire and Wigtownshire.

In Ireland the breed is well established in the north, west and southwest.

In northern England, unlike Scotland, a flock book is kept, but the number of Scottish Blackfaces is comparatively small and they do not extend far south of the border. However, other closely related breeds occupy the hills as far south as Derbyshire.

RELATED BREEDS

These breeds are more local in their distribution, and are not numerically so important. They are the:—

Swaledale which is darker in its face and leg colouring at birth; however, the black hairs later become more or less thickly interspaced with white round the muzzle and sometimes above the feet; the wool is finer and shorter.

The *Rough Fell* which has typically a grey muzzle and black face frequently tinged with brown (54); the wool is coarse.

The Lonk, which is the largest and least hardy of the Blackfaced group, has a closer, finer and heavier fleece; there is typically a considerable area of white on the face.

The *Derbyshire Gritstone* is not typical of this group except in its face colour and the fact that it is a mountain sheep; its body conformation is quite different; the fleece is close and finer; the breed is hornless.

FLEECE CHARACTERS

Owing to the habitat of the Scottish Blackface sheep, the fleece is of primary importance for protection, in spite of which the fleece is of considerable commercial importance.

The fleece consists of wool, long hair fibres and kemp (7, 9). The wool is fine and not of great length. The long hair fibres are much coarser

and longer than the wool, varying in growth from a few inches to over a foot yearly. The kemp is even coarser, more brittle and of irregular length; its distribution on the body is uneven. Another undesirable character of kemp is the fact that it grows during the summer and early autumn and is shed in late autumn (17). Manufacturers object to kemp because it cannot be readily dyed and because of its brittleness. The inheritance of kemp depends upon a multifactor basis; the lower degrees of kempiness show a tendency to behave as partial or incomplete dominants over the varying higher degrees of kempiness (11). The percentage of kemp in a Blackface fleece may vary from under 1% to over 30% (10).

The birth-coat fibres also consist of three main groups (14)—wool, a heterotype, with a whip-lash shaped tip which develops into hair, and another heterotype, with a sickle-shaped tip which falls out after some weeks and is followed by kemp (28). There is a popular belief, especially among breeders of Welsh Mountain sheep, that the presence of kemp is a sign of hardiness and that the birth-coat fibres which precede kemp are of great importance to the newly born lamb.

In 1788, the Blackfaces of Yorkshire were stated to yield fleeces of 1½ lbs. from store ewes and 2½ lbs. from vale-fattened wethers; it was then stated that the "covering of their buttocks is mere hair, resembling the shag of the goat rather than wool" (38); however, this was regarded as a mark of hardiness and accordingly a coarse woolled shaggy ram was preferred.

In 1799 the fleece weights in Clydesdale were 4 lbs. for wethers, 3 lbs. for yearlings, and 2.7 lbs. for ewes (5, 56). A few years later in Argyllshire, the average weight was given as 2.8 lb. while elsewhere the "Heath" breed, one of the many names the breed bore, was then stated to yield 3 to 4 lbs. (15).

Some 40 years later body size had increased, but fleece weights were still only about 3 lbs. (62). By 1884 fleece weights had increased up to an average of 2½ lbs. to 5 lbs. for ewes, 3 to 5 lbs. for yearlings and 3½ to 6 lbs. for wethers (5, 31). Part at least of the increased weights had been achieved by increasing the length of the staple, which then averaged 9 or 10 inches, but occasionally reached 15 inches. In descriptions of the breed written this century the estimate of fleece weights has usually been about 3½ to 4½ lbs. (2, 12, 30, 35, 57). It has been noted (34) that the average for ewe fleeces from the coarse-wooled districts was 4 to 5½ lbs. and from the finer wool districts of Argyllshire, Invernessshire and Rossshire, only 3 to 4 lbs.

These figures show that a considerable advance in fleece weights has been made in the last 100 years. Nevertheless, there is undoubtedly still room for considerable improvement, since it is not unusual to obtain a fleece weighing 9 lbs. from some coarse-wooled ewes under hill conditions, while fed rams, in particular, may considerably exceed this figure. One of the easiest ways of increasing fleece weights in Blackfaces is to select for a longer staple. This is undesirable if the sheep are to be grazed on ground where snow occurs, on muddy ground, or on ground covered with low woody vegetation, such as heather. A long staple encourages "snow-balling" or "mud-balling" on the end of the lower staples, and it catches on woody heather in the spring. But a dense fleece not only increases weight, it also increases protection.

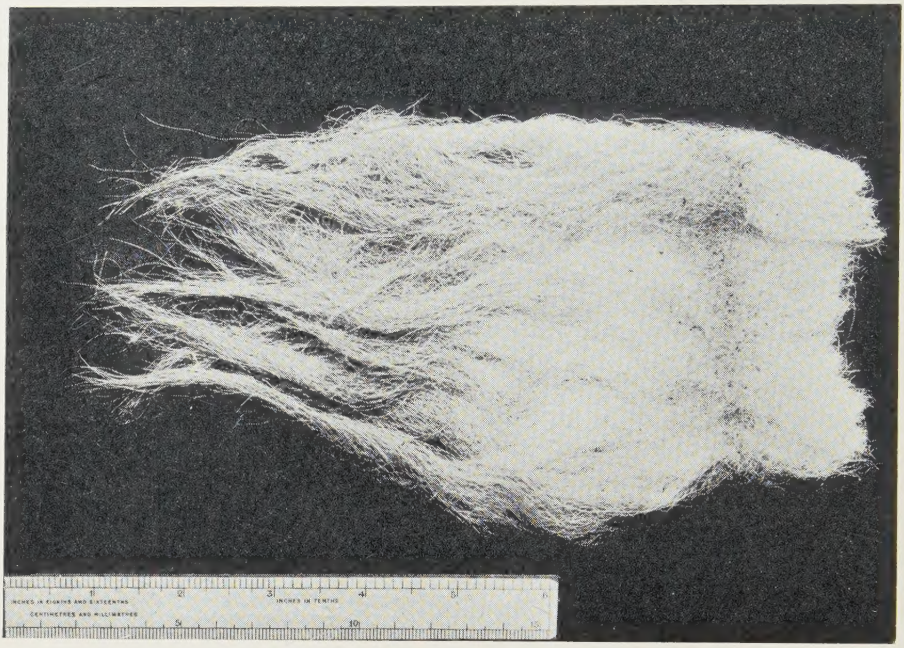

FIGURE 1. Blackface wool from Wigtownshire. ×0.6.

FIGURE 2. Blackface wool from Lanarkshire—mattress type. ×0.38.

There are such considerable variations in the character of Blackface fleeces that they are used for entirely different manufacturing purposes. The characters of the hairy fibres determine the grades into which the wool is classed.

The shortest, finest, Blackface wool is used for tweeds, especially "Harris" tweeds, for an inferior type of hosiery and for making coarse blankets. These wools come from the Outer Hebrides, parts of Skye and the west coast of Rossshire. It is of interest to note that the finest Cheviot wools also come from west Rossshire. Some ewe fleeces from all districts of Scotland and northern England and from Swaledale sheep are used blended for these trades.

Another type of wool produced by some Blackface sheep, chiefly yearlings, in the Galloway district, is fairly short, has a silky bottom and no "starey" top; this wool is used for yarns of a better class than carpet yarns. Similar fleeces are obtained in smaller numbers from districts other than those which produce fleeces of "tweed" or "mattress" types (Figure 1).

Carpet yarns are made from the finer intermediate types of Blackface fleeces, and according to the requirements of the market they may absorb the coarser of the fleeces already described or the finer "mattress" fleeces.

Mattress wool is the coarsest of the Blackface wools, and is obtained from Lanarkshire and the western districts of Peebleshire (Figure 2). Slightly finer, but still classed as mattress wools, are the fleeces from Stirlingshire, and the southern Highland districts of Perthshire, with a northern limit about Glen Lyon. The belt of medium-coarse wools extends eastwards to some farms in Angus and westwards to Argyllshire, but as the coast is approached the fleeces tend to become finer; similarly the wools from Loch Rannoch to the Great Glen, and especially in the latter district, tend to be of a finer quality. The wools of north Northumberland are of the finer mattress type; they become finer farther south.

In Ireland, the finest Blackface wools come from the west of Connermara, there they have probably been influenced by the incorporation of Cheviot blood. The wool grown in Kerry is of fine quality.

PROBABLE CAUSES OF DIFFERENT FLEECE CHARACTERS

In addition to the genetical aspect, there are undoubtedly several other causes for the various wool types which occur in different localities. Many of these causes must act on other breeds in other similar localities; sometimes these influences may be accumulative, under other conditions they must tend to cancel each other.

Rainfall, temperature and sunshine are undoubtedly most important, not only directly but through their affect on the herbage and its nutritive value and on the free-living stages of internal parasites. However, a study of maps of the average rainfalls, temperatures and hours of sunshine (3) shows that none of these alone can be considered to account for the distribution of the various types of Blackface wool. The closest connection appears to be between the monthly averages of the night isotherms for the later months of the year. It is a well known fact that the climate of the west is more humid and mild than that of the east of Scotland; this has a considerable effect on the herbage. Even Bamboos will grow in one locality on the west coast of Rossshire.

It has been stated that a "humid" atmosphere has the effect of lengthening the covering of sheep as well as of other animals" (31), and that, "when Blackface sheep of Lanarkshire type, bred in Dumfriesshire are taken to Renfrewshire, a rainier district, their progeny soon acquire on their backs the thick, close-set 'foggy' wool which protects the skin from rain water. In Perthshire these sheep develop finer and shorter wool all over the body . . . . In Invernessshire the coats of similar sheep do not grow so heavy or so strong and coarse in fibre" and "when sheep are migrated to the wetter west they assume longer and more open fleeces" (53). These observations infer that rainfall is the direct cause. But the same authors also suggest that the depth and quality of soil influences the character of the fleeces and that the heavy clay soils and bogs superimposed on the coal measures are responsible for the long, heavy coat of coarse fibres which is typical of the Lanarkshire Blackface, and that on Limestone the quality of the wool improves, but the quantity diminishes.

Minerals may influence the fleece, though the pasturage and they themselves can be considerably modified by rainfall. For example, phosphorus and potassium are increased and calcium decreased by excessive rainfall (44). It has been shown that the West Highland pastures are comparatively deficient in calcium, phosphorus, potassium and chlorine, and that these deficiencies are even more pronounced in the Island of Lewis where nitrogen is also very deficient and the grazing value very low (1). These are fine wool areas. Experimental feeding trials, with concentrates and minerals to free-grazing Blackfaces, have proved that, on the west coast of Scotland, an increased wool yield results when they are available (45). It has also been noted that free-grazing animals eat most readily those grasses with the highest mineral content (44). Iron is another mineral which influences the growth of wool (16); data on its distribution in the grazings used by the different types of Blackfaces are lacking.

An interesting example of the influence of different types of grazing occurred in Dumbartonshire. A hill farm consisted of one half heather and the other half grass and scrub; otherwise the two portions of the hill were superficially essentially similar. Each heft was stocked with homebred and brought-in ewes, the latter having been bought as lambs, from the coarse-wooled district of Lanarkshire. The sheep feeding on the heather retained their natural fleece; the homebred sheep had the intermediate wool expected in that locality and the Lanarkshire sheep retained their coarse wool. The sheep feeding on the grass and scrub, both native and Lanarkshire were fine-fleeced; the majority of the brought-in ewes were finer than the local sheep on the heathery ground. It has been noted before (31) that sheep on grassy hills are finer fleeced than sheep on heather. However, the belief that the reverse holds true is held by too many sheepmen for a few isolated cases to be accepted as proof. Variation in the grasses which constitute the grazing may account for contrary results.

The commonest hill grasses are the Bents *(Agrostis vulgaris* and *A alba)*, the Red Sheep's Fescues *(Festuca rubra)* and Sweet Vernal *(Anthoxanthum odoratum)* (52), but many others occur and may be locally important.

Analyses of these commoner hill plants and grasses show great variation in their composition. Heather is comparatively rich in ether-soluble substances, but low in ash (55).

It has been stated that the "greatest areas of heather coincide with the poor quartzitic hills of Rannoch and Atholl, while the greatest areas of pasture, on the other hand, coincide with the rich schists, containing calcium, magnesium and potassium of the Breadalbane range" (51), which lies just south of Glen Lyon; this glen has previously been mentioned as a dividing line between wool types. The writer's farm lies just south of it. A limestone formation runs through the farm, on which the grazing however, is largely heather; a mattress type wool is produced.

Because of the many small but important local variations in geological formations, and the local variations in fleece types caused by breeding, etc., it has been impossible to formulate theories on the influences of soils, in producing the various classes of Blackface fleeces.

Age has a considerable influence on fleece characters in the Blackface breed. Yearlings have the longest fleeces, partly because of the lower period of growth, but the wool is also coarser than that of older animals. With age, both ewes and rams become finer in the fleece, owing to the decrease of hair fibres.

Rams as a rule have coarser wool than ewes; this tendency is accentuated by the custom of housing and feeding rams during winter.

Parasitic nematodes may be another factor which causes fining of wool. Sheep which have been infected with Liver fluke, some other diseases and partial starvation, frequently show a "break" in the fleece fibres; this may eventually cause shedding of the fleece. Nematodes, unless they cause death, are seldom so drastic in their effect, but they may be more persistent; therefore, it can be expected that instead of causing a definite "break" they may cause a fining of the fibres. Nearly 50 years ago it was stated that the main source of mortality of sheep in western Argyllshire was caused by worm parasites, particularly those infesting the lungs and alimentary tract (22). Six or seven years ago, it was found that in the same district and in the southwest of Scotland, both fine wool areas, a very high incidence of infection with nematodes existed; but that in the coarse wool areas of Lanarkshire and Perthshire the hill sheep were only lightly infected (13). Further confirmation is given by the fact that it has been shown that sheep infected with the small intestinal trichostrongyle, *Cooperia curticei*, produce lighter pelts, with finer wool fibres, than non-infested sheep, and that uninfested sheep are more able to utilize calcium and phosphorus (4).

Heredity undoubtedly is another important factor in producing the various wool types. The earliest improvement in the Blackface breed centred around Lanarkshire. A coarse wooled sheep looks larger and therefore sells better; it was selected as the desirable type. With the improvement in communications, rams from Lanarkshire were frequently used in Perthshire and Stirlingshire. In Argyllshire these rams were subject to a heavy death rate, therefore they were less frequently used, so a larger proportion of locally bred rams were needed. If the flocks of Argyllshire originally contained blood from the original soft-wooled dun or white face sheep, which has been shown to be almost certainly the case, this taint, therefore, tended to be perpetuated rather than be bred out, as has occurred elsewhere. Moreover, there is a local belief held by many farmers and shepherds that the soft-wooled sheep make the better milkers,

and since mutton is the principal consideration there would even be a tendency to select soft-wooled animals for breeding. Similar factors have operated in the Islands and western Rossshire.

In Galloway the Wensleydale has been frequently used for crossing with Blackface ewes. The progeny have undoubtedly sometimes been retained even in hill stocks and have gradually become intermingled with Blackfaces. This is confirmed by the more curly fleece characters and by the flatter conformation of the face of many Galloway stocks.

BLACK SPOTS

In 1796 about 3% to 5% (5) were self-black lambs and black spots on the fleece were noted as very common (12). At the present time the percentage of self black lambs is probably well under 1%, with a tendency to be highest where unfavourable conditions made it most difficult to keep up the sheep stock, and where selection is therefore most limited.

The same considerations apply to black spotting. Its commercial importance varies according to the situation of the spot or spots; those situated on the edges of a shorn fleece are more easily cut out than spots in the centre (see Figure 9). Black spotting is commonest on the tip and root of the tail. A spot at the back of the neck or even a collar is common. The scrotum is frequently covered with black wool, and there is often an extension of pigmentation from the hair-bearing skin of the legs upwards into the wool-bearing skin of the forearms and thighs. Body spots are less frequent, but still too common. Black is the usual colour of these spots, but brown-red spots do occur.

BLACKFACE CROSSES

Old Blackface ewes are frequently mated with Border Leicester and Wensleydale rams, less frequently with rams of Down breeds, to produce early lambs on low ground. Occasionally they have been mated with rams of other breeds in attempts to incorporate improvement in the Blackface breed; the majority, at least, of these experiments have been failures.

The most common cross to produce early lambs is with the Border Leicester ram; it has been used for over 130 years (15). The commonest name for the offspring is "Greyfaces". "Blueheaded" Border Leicesters and dark faced Blackface ewes are preferred, as butchers believe the lambs from such matings are the best 'killers'. Some 'Greyface' females are retained for breeding with Down rams to produce early maturing lambs, since Greyface ewes are good milkers and frequently produce twins. The 'Greyface' fleece is lustrous, slightly stapled and long with some crimp.

The cross between Blackfaces and Cheviots is generally accidental, but common where Blackface and Cheviot hirsels adjoin. This cross, like many others, is known as a "Mule"; it is far from pleasing. The colours are indefinite, the crown is coarse; Blackface breeders, to avoid trouble at lambing, have almost standardized a level crown, Cheviot breeders have not had to breed for this character. The fleece is intermediate between that of the two breeds. A hundred years ago this cross was condemned as unsuccessful, unless it had to be used to change the stock on a hill (29, 62).

Suffolk rams are occasionally used to produce an easily fattened lamb of good size suitable for killing in the later summer. The females of this cross are seldom used for breeding.

Lincoln rams crossed with Blackface ewes produce bigger and coarser lambs than do any other rams. It was in favour 50 years ago. The males have small ill-shaped horns. The colours are similar to those of a Greyface. The fleece is longer than that of a Blackface, more lustrous, crimped and stapled.

Crosses with Shetlands are rare. The lambs have short tails. The lamb wool is dense and long, varying from straight to tightly curled. Face colours vary from that of a Greyface to black. The horns are strong and rams may have four (20). It has been suggested that the colour "Sheila" of Shetlands, originated through the incorporation of Blackface blood (20, 21).

The cross between the White Welsh Mountain and the Blackface produces lambs which have the face colour patterning of the Blackface, but the black areas are replaced with dark brown, reddish brown or grey; the colouring of the legs is similar. The body spots tend to be redder; the red heterotype fibres of the Welsh stand out above the other fibres. A spot at the back of the neck is common. The curl of the birth-coat varies from wide and open to fairly tight.

The cross with the Black Welsh gives a black lamb, which is otherwise similar in conformation and birthcoat (50).

It is probable that Lonk rams have been used in Blackface flocks more extensively than is generally admitted. The object of their use is to increase size. However, it is doubtful whether this object can be attained so simply, although the longer leg, lighter colour and fluffier fleece of the cross tend to give the impression that it has. On low ground, the crosses appear to be no larger than Blackfaces would be on similar land, for the type of grazing available makes a vast difference to the size which Blackfaces will attain. Most ewe lambs of this cross would be taken for pure Blackfaces, but with age the crown becomes "harder", the fleece more frizzy, with a smaller staple and generally has more kemp. The back cross to a Blackface ram has the disadvantage of a more open fleece, with as many black spots as a pure Blackface. Some years ago the cross was common in Yorkshire; the females were kept and mated with a white faced ram.

A few attempts have been made to improve Blackface wool by crossing with Gritstones. The results have been most irregular and not promising. Fleece weights tend to be unduly light. Black spotting is as prevalent as on the parents. Fleece types vary from that of Gritstones to that of inferior Blackfaces; generally the wool is longer than that of Gritstones but shorter than that of Blackfaces; however, there appears to be a tendency for the fleece to follow the male parent type; some fleeces are of best carpet trade grade. Many of the crosses have the weak rump of the Blackfaces and the narrowness and shallowness of chest associated with the Gritstones. When the cross is made with a Gritstone ram the females are usually polled and the males have small horns. When the reverse cross is made both sexes are horned. The crosses have the longer tail of the Gritstone. Unfortunately only a small number of Gritstones and Gritstone-Blackface crosses have been observed on land heavily infected with Bursate nematodes, but the results with the few animals available suggested that both the pure Gritstones and the crosses were less resistant to helminthiasis than Blackfaces or Cheviots.

Another observation made on a very small scale suggested that Southdowns are less resistant than Cheviots to haemonchiasis. It might be expected that mountain breeds of sheep and horses would have less inherited resistance to helminthiasis than low ground breeds, because low-ground breeds are more exposed to heavy infections and there might, therefore, be more elimination of the least resistant. It is accordingly surprising to find that it has been noted (47) that Welsh ponies, normally relatively free from Sclerostomes, become much more susceptible when Lowground sires introduce other blood.

Crossing Blackfaces with Merinos on hill ground would probably end in failure if Merinos transmitted their herding instinct and dislike of alpine plants. On low ground a few crosses with Blackfaces have been most promising. The density of fleece imparted by the Merino persisted so markedly until at least the fourth back cross to the Blackface, that one or two pounds more wool might be expected. The first cross is very plain in both body and head. The hard Blackface hoof appeared to be sufficiently dominant to counteract the foot trouble usually experienced with Merinos and Merino crosses in Britain.

Crossed with Southdowns, Blackface ewes produce lambs with legs which are short and wide, with well-muscled thighs, but with weak fore-ends. Face colour may be patterned or whole-coloured with a "mousy" or a darker brown. Young sheep of this cross are less hardy than pure Blackfaces. The cross is early maturing; nearly a hundred years ago it was liked (29). The fleece varies from that of an inferior Southdown to that of a soft Blackface; it may be consistent in one animal and vary from area to area on another animal, but it tends to be dense and can be almost kemp free. The F_2 generation is most irregular in body conformation and fleece characteristics (24).

Kerry Hills has been crossed with the Blackfaces in attempts to unite the wool characters of the former with the hardiness of the latter. The wool of the cross is of soft carpet quality. Black spotting is not eliminated. Cross ewes make excellent mothers. The Kerry Hill Breed is not thoroughly fixed, some ewes having almost a Clun Forest appearance; therefore considerable irregularity must be expected in the cross.

All the available evidence points to the fact that there is sufficient face colour in all Blackface crosses to make then immune to the disease "Scrapie".

FACE COLOUR

The face colour of Scottish Blackface sheep may vary from a black without any white to one which has only a little black colour; however, there is practically always some black on the muzzle, on the margins of the forehead and around the eyes. Between the extremes there is almost every variation. In recent times there has been some preference for a "brocket", named after its vague resemblance to the face markings of a badger; this marking is not the "badger-face pattern" of Welsh Mountain, Cheviots and some non-British sheep described by Roberts (49). Other common patterns are a star or blaze on the forehead and ticks on the side of the nose; the latter often meet over the bridge of the nose like an inverted "V", and may join the white markings of the forehead. There is a preference for the black and white markings to be clear cut. In some

ewes and rams, generally the darker, white hairs infiltrate the black area around the muzzle; they are known as "mealy nosed" (Figure 3). This colour is liked. Brown, increasingly with age, may tinge the black areas, especially under the eyes; this is disliked. The darker faced ewes and rams are, in some areas, considered the most hardy and the white faced ewes are expected to be the better milkers. "Muff" may also be considered a face character; it consists of soft wool around the cheeks and on the forehead; on the latter area it may be some inches in length and coarser than on the cheeks; it should be removed in country liable to snow storms (Figure 3). Some Blackfaces are free of it. Muffiness of the face and legs is considered another indication of a good milker with a well-wooled belly. It has been stated (39) that "in this breed presence of wool on the forehead is dominant to its absence. We must postulate more than one pair of allelomorphs, however, to account for the variations in degree of 'muff' which are encountered in this breed".

FIGURE 3. A Blackface ewe with an excessive amount of "muff" and a "mealy" nose.

Apart from the possible influences of the breeds which were established in Scotland before the arrival of the Blackfaces, it must be remembered that, if dark-faced ewes were then believed to be the hardier and light-faced ewes the better milkers, there would be a tendency to use darker rams in the central higher area, where it might also be considered a stiff wool was necessary to shed the rain, but in the milder west breeders would risk the use of lighter-faced rams to obtain better milkers; thus these types would be linked with different districts and the beliefs would be perpetuated.

Owing to the interest and possible practical importance, especially when selecting rams, of knowing whether these various local prejudices were founded on fact or not, records of the flock at Morenish were kept for over 10 years from November, 1922. Each sheep bought or born was numbered with an ear tag; records were kept of face colourings (later supplemented with photographs) of black spotting, of size, of kempiness and of horn carriage. Owing to lack of knowledge then of the biology of kemp and because rams' horns are frequently artificially trained, records of the last two characteristics were worthless. In addition, records were kept of matings, number and sex of lambs born, etc. With the exception of lambs born late in the season it was possible to keep accurate records of parentage. Naturally some rings were lost, many sheep died through braxy, trembling, casting or couping, etc., and some were "black loss"—died and were never found. But there is no reason to believe these losses did not affect all types equally. In all some 3,500 animals were recorded in 10 years.

Face colour was recorded on the following scale:—

A0. represented a completely black face.
A$\frac{1}{2}$. signified a very little white, 1 to 7% (Figure 4).
A1. was used for 8 to 15% of white (Figure 10).
A2. was the value given to 16 to 35% of white (Figure 5).
A3. signified 36 to 55% white (Figure 11).
A4. represented 56% of white and over (Figure 6).
A5. would have been the value given to an all-white face, if it had occurred.

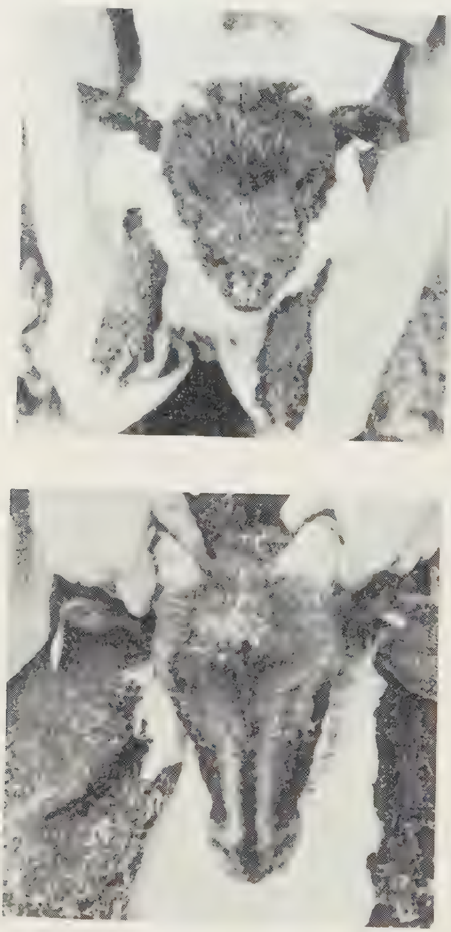

FIGURE 4. A ewe lamb of face colour A$\frac{1}{2}$ and the same sheep at 14 months old.

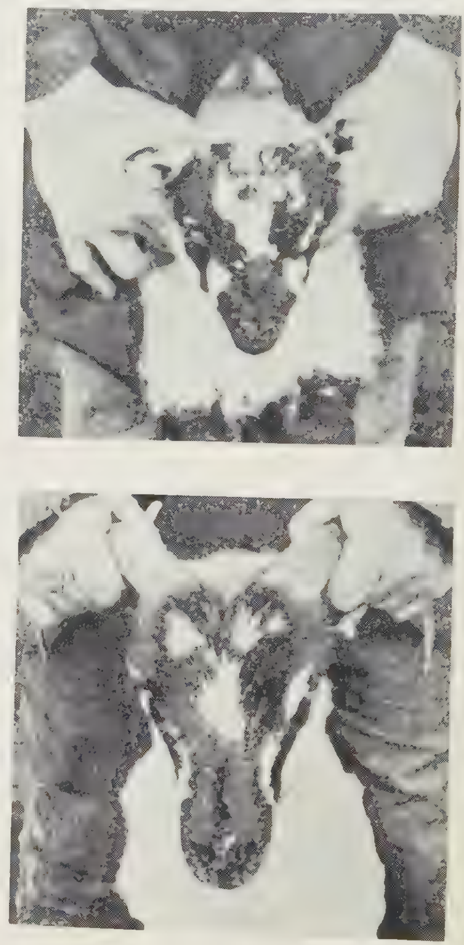

FIGURE 5. A ewe lamb of face colour A2 and the same sheep at 14 months old.

Prior to the autumn of 1929, these values were estimated; subsequently the faces of the sheep were also photographed with a Leitz "Leica" camera at a distance of 3 feet. In the laboratory the negative was placed between two sheets of glass, put into a projector, which cast the image of the head on to squared paper, magnified about 20 times. The number of

squares covered by the white were counted and reduced to a percentage of the whole. As the forehead is comparatively flat, and the nose rounded, but all had to be estimated on a flat surface, the values of the top and lower halves of the face were counted separately. However, errors caused by the shape of the face were constant. The "mealy" noses of adults were counted as black, as they were black as lambs.

It is known by shepherds that lambs gradually become darker in the face as they age; however there were no exact data on the amount of change which takes place. Therefore, photographs were taken of 137 young lambs and the same lambs were photographed in the late summer, when 4 to 6 months old; 53 female lambs were also re-photographed when 14 months old.

The average amounts of change which occurred in the foreheads and lower faces of 137 lambs with advancing age can be noted from Table 1. It will be seen from Figures 4 to 6 that some of the darkening is caused by the fact that the constantly dark areas

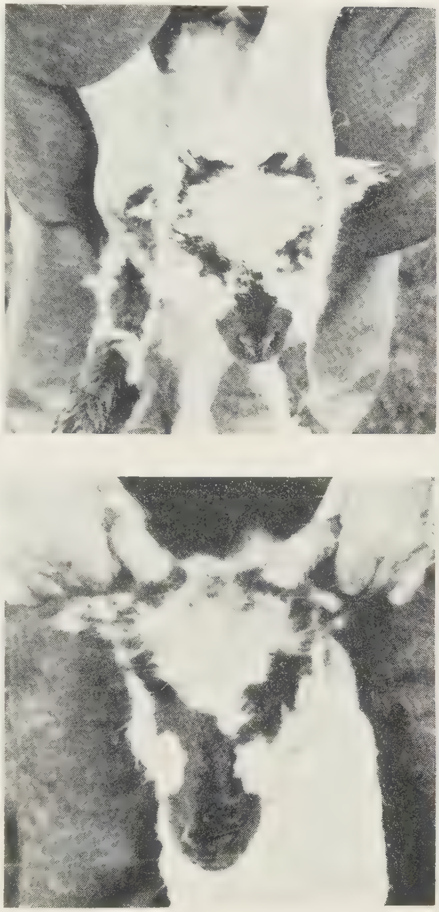

FIGURE 6. A ewe lamb of face colour A4 and the same sheep at 14 months old.

TABLE 1.—FACE COLOUR CHANGES IN LAMBS*

—	Young lamb's forehead	Old lamb's forehead	Young lamb's lower face	Old lamb's lower face	Young lamb's whole face	Old lamb's whole face
	%	%	%	%	%	%
A0. (0% white)	0	0	0	0	0	0
A½. (1–7% white)	4	Under 1	2	Under 1	3	Under 1
A1. (8–15% white)	16	4	7	2	11	3
A2. (16–25% white)	24	12	15	7	20	10
(26–35% white)	42	23	23	10	32	17
A3. (36–45% white)	51	30	29	14	41	23
(46–55% white)	60	41	41	24	51	33
A4. (56–65% white)	75	57	46	32	61	44
(66–75% white)	89	71	51	38	72	54
(76% and over white)	95	70	68	46	83	59

*Table 1 shows the average face colour values of 137 sheep, valued at birth and at about 4 months old.

FIGURE 7. The stepped line indicates the percentage of white on the faces of 136 lambs; the percentage of white on their faces at the end of summer is indicated by the solid black, and in the six lambs on whose face the percentage of white increases by the hatched column.

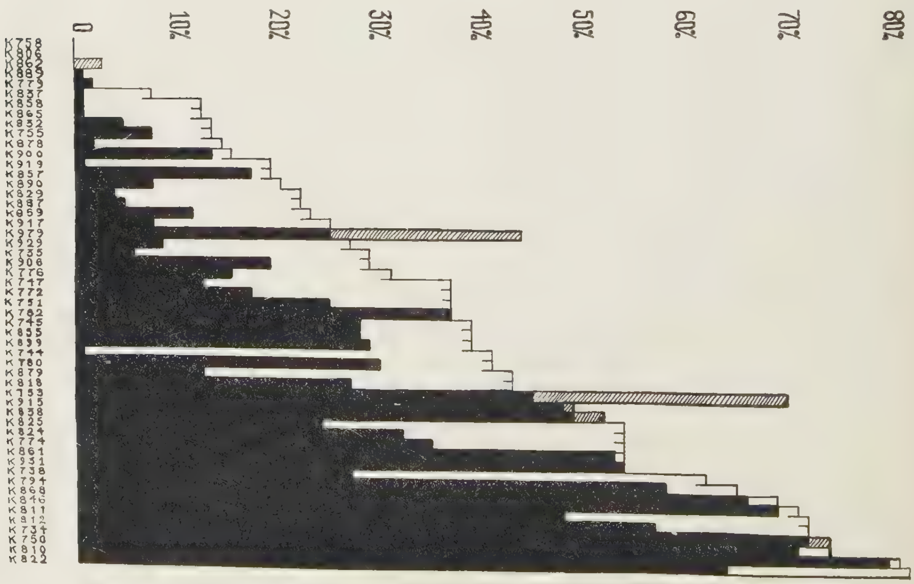

FIGURE 8. A similar histogram for 53 ewe lambs, which were re-photographed at 14 months old.

around the muzzle and eyes are areas which grow most rapidly, and that some of the white, especially around the edges of a marking, tends to disappear.

Figure 7 shows the amount of change which took place in the whole face of each of 136 lambs. The stepped line shows the percentage of white in the face of the young lambs; the shaded area the percentage of white when a few months old; for the few lambs in which the percentage of white increased the amount is shown by the hatched column.

Figure 8 shows the data arranged for the 53 females which were rephotographed when 14 months old. It will be seen that practically all the change takes place in the first few months of the lambs' lives.

FACE COLOUR INHERITANCE

With a few exceptions, such as Wood (59), who in 1903 crossed Suffolks with Dorset Horns and later raised an F_2 generation, little work has been done on the genetics of the face colour of sheep. These results were analyzed by Roberts (48) 10 years ago; he grouped the breeds of sheep as regards face colour into those with whole colour on the face, such as the Suffolk, those with very white faces, such as the Dorset Horn, and those with broken colour on the face such as the Scottish Blackface and Kerry Hill. The F_1 lambs of the Dorset Horn and Suffolk cross "had speckled faces of a more or less uniform kind, with some tendency to the formation of a pattern around the nose and eyes", a pattern which is similar to many Blackface lambs. Roberts suggests that, in the F_2 generation, if AABB is a black face and aabb is a white face, then AABb, AaBB and AaBb will have speckled faces, and AAbb, Aabb, aaBB and aaBb will have patterned faces. Kerry Hill-Merino and Border Leicester-Blackface crosses and pure Kerry Hills have confirmed this.

A hundred years ago (62) and ever since, breeders have thought it desirable not to have an excess of white in the face-colouring; that this has been possible without producing a high percentage of completely black faced sheep indicates that face colour of Blackfaces depends on more factors than the somewhat similarly coloured cross between the Suffolk and Dorset Horn would suggest. Moreover, assuming that two factor pairs, with intermediate inheritance, are responsible for the main distribution of colour and white on the face, whole black face and whole white face being the homozygous type, the latter would frequently occur if two pairs of factors alone were the cause of face colour. But the writer has never seen, or heard of, a completely white faced Blackface. In the F_1 generation of the Blackface × Cheviot and Blackface × Border Leicester an appreciable percentage of white faces occur. In the flock of Blackfaces from which these data were collected only about 5% had black faces.

The genetical analyses which have been made on the causes of spotting in guinea-pigs (60) and mice (18, 19) suggest that very similar explanations may be true for face colour in Blackface sheep. It seems probable that Blackface sheep carry a gene or genes, which cause the blaze on the forehead and ticks on the side of the nose, and other common markings comparable with the gene of guinea-pigs which causes a facial streak, or with the 4 genes of Arabian horses, three dominant and one recessive, which act as modifiers on the 4 areas of the face when a factor for white markings

allows them to be expressed (8). Sufficient photographs were not taken in this flock, and the original method of assessment was too vague, to allow this suggestion to be proved. Moreover, the presence of modifiers, comparable with those of guinea pigs and mice, could account for the absence of white faces and comparative scarcity of black faces. The absence of some of the modifiers in white-faced breeds could account for some white face lambs occurring in crosses. The limited amount of photographic data has also prevented any attempt to assess the effect of non-genetic variability, such as the effect of sex and age of the dam.

Owing to the irregular change in face colour between birth and a few months old, a fact which was not sufficiently appreciated when these records were first made, and because the face colour of the lambs was assessed soon after birth, it seems necessary to restrict the analysis of face colour inheritance to the lambs whose dams' and sires' face colours were both recorded at birth. The number is small because bought-in rams were chiefly used in this flock, and only rams with face colours of values A_2, A_3 and A_4, which left 119, 76 and 96 lambs, a total of 291, are available. However, these rams were mated to ewes of the 6 face colour values.

Table 2 shows the classes into which these lambs were valued. Table 3 shows the result of correlating the "mid-parent" value, with the value of the lambs. For the purposes of these tables, A0 was given a value of 1, $A\frac{1}{2}$ of 2, and therefore A1 to A4 were changed to 3 to 6.

Table 4 shows the correlation coefficients (r) which were obtained between the ewes and lambs, when grouped according to the face colour of the ram. When the face colour values of the lambs were correlated with that of the average face colour value of their dams and sires, a figure of $r = 0.1872$ was obtained for the 291 observations; for $P = 0.01$ the necessary correlation is $r = 0.151$.

Table 2.—Face colour inheritance*

Ram's face colour	Lamb's face colour	Ewe's face colour					
		1	2	3	4	5	6
4	1	2	2	1	1	–	–
	2	2	3	3	4	1	–
	3	1	1	3	8	5	1
	4	–	1	2	11	8	7
	5	–	–	6	6	15	11
	6	–	1	–	3	6	4
5	1	1	–	–	1	–	–
	2	1	–	1	–	–	1
	3	2	2	3	3	1	–
	4	1	7	2	5	6	2
	5	1	1	5	5	11	6
	6	1	–	2	–	3	2
6	1	–	–	–	–	–	–
	2	–	–	3	2	–	–
	3	–	2	–	4	1	–
	4	–	1	4	10	4	2
	5	1	–	6	12	16	6
	6	1	–	1	8	5	7

*Table 2 shows the frequency distribution of lamb face colour distributed according to the face colour of sire and dam.

TABLE 3

		"Mid-Parents" values							
		2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Lamb values	1	2	3	1	1	1	–	–	–
	2	2	4	3	5	4	2	1	–
	3	1	3	5	13	8	6	1	–
	4	–	2	9	14	17	23	6	2
	5	–	1	8	11	26	34	22	6
	6	–	2	1	5	7	15	7	7

Table 3 shows the same data as Table 2; the frequency distribution of lamb face colours according to the average face colour values of the dam and sire—the "mid-parent" value.

TABLE 4*

Ram face colour	Number of comparisons	Observed correlation of ewe and lamb face colour (r)	Necessary value for r	
			$P = .05$	$P = .01$
A2	119	.204	.178	.234
A3	76	.194	.223	.291
A4	96	.267	.199	.259

*Table 4 shows the correlation with ram groups between the ewe face colour and lamb face colour.

Unfortunately, as there are no figures available of the effect of mating with the darker faced rams, the results, shown in Table 4, for the different lighter faced ram groups, are too limited to warrant conclusions. The tables do indicate, however, a correlation between the face colour of ewes and their lambs.

Moreover, these data confirm the expectation of shepherds that the majority of lambs will possess a face colour midway between the face colours of their parents, and also suggests that the face colours in Blackface sheep depend on multiple factors.

FACE COLOUR AND BLACK SPOTTING IN THE FLEECE

Black spotting (Figure 9) on the body of the lambs was indicated by a system similar to that originally used for the face colour value, e.g., a lamb valued at E0 had no black spots, E$\frac{1}{2}$ was used for a lamb with a small black spot (often on the neck or on the root of the tail) and so on up to E5, which indicated a black lamb.

Table 5 shows the frequency of distribution between face colour and black spotting of 2,156 lambs, the progeny of about 60 rams.

Statistical analysis indicates a correlation of $r = .1906$. This correlation with $n = 2156$ is highly significant, indicating a real relation between whiteness of face and comparative freedom from body spots. This confirms the generally accepted expectation that black-spotting is less common on the white faced sheep. However, Table 5 also shows that it is possible to have black faced lambs which are free of black spotting, although they are comparatively rare.

FIGURE 9. A Blackface lamb showing typical "black spotting"—value E2, if no spots on the other side of the lamb; if there were, value E3.

TABLE 5*

Face colour values	Black spotting values						
	E5	E4	E3	E2	E1	E½	E0
A0	3	6	18	31	32	25	2
A½	0	2	14	20	64	110	18
A1	0	2	20	39	98	176	52
A2	0	1	13	66	112	302	158
A3	0	4	6	33	87	224	202
A4	0	1	5	3	20	73	114

*Table 5 shows the frequency distribution of lamb face colour and fleece spotting.
$r = .1906$.

In this flock the use of black spotted rams and ewes, especially the former, has, as far as possible, been avoided. However the analysis of 838 lambs, the progeny of 21 rams and 765 ewes shows that the average value of the lambs corresponds very closely to the average of the parents. Thirteen rams without spots (E0) mated to 535 ewes with an average value of E1.23 for spots, left lambs with an average value of E0.65. Three rams of value E½ and three of value E1, mated to 86 ewes averaging E0.98 and 138 ewes averaging E0.73, left lambs averaging E0.63 and E0.80. Two rams of the value E2 were mated to 6 ewes averaging E1.66, the six lambs averaged E1.75.

This evidence shows that the incidence of black spotting could easily be considerably reduced with careful breeding.

FACE COLOUR AND MILKING CAPACITY OF EWES

In 1930 and 1931 an attempt was made to determine whether or not the popular belief that face colour and milking capacity are associated was founded on fact. Obviously there was no practical method of directly estimating the milk yield; therefore, it was decided that the dead weights of the male and wether might be used as an indication. The errors which may be involved are numerous, but the practical importance of the belief, it is hoped, justify the publication of these data. Where lambs were obviously stunted through the loss of their dams, by mytosis and other diseases, they were arbitrarily disregarded; fostered lambs were also disregarded unless fostered by ewes of the same face colour value. The influence of genetic factors for growth may be of considerable importance, but the farm is one which appears to limit the size to which the sheep will grow; of necessity this factor has been disregarded. Moreover, a study of the sires and grandsires of the lambs showed that the most used rams were represented very evenly throughout the various classes. The age of the dam has been disregarded (although "gimmers"—two-year olds—are expected to have less good lambs), because it was believed that there was little difference in the face colour values of the various age groups of the dams. All lambs were weaned at the same time; they were then grazed for a short time on rape and foggage; the financial aspect necessitated this.

In Table 6 the average dead weights of the lambs are given grouped according to the face colour values of their dams. In Table 7 the differences between the average dead weights of the six groups are given, and also the differences necessary to show that the results were unlikely to be the result of random sampling.

On the hypothesis that face colour has not affected lamb weight one would expect no difference in mean weights of lambs from ewes of differing face colour groups. Some allowance must, however, be made for the variation in those weights caused by the many other factors on which weight depends. The extent of the effects of such factors is indicated by the "necessary difference" (see Col. 4, Table 7).

An observed difference in average weight greater than the "necessary difference" may therefore be taken as indicating a real effect of face colour on lamb weights.

TABLE 6*

Year	Ewe face colour groupings					
	A0	A½	A1	A2	A3	A4
1930	(8)23.6562	(7)23.00	(18)24.146	(22)21.773	(14)23.785	(11)22.670
1931	(5)22.288	(6)21.75	(15)24.079	(22)22.277	(20)22.984	(10)20.687

*Table 6 shows the mean dead weights in pounds of lambs slaughtered in 1930 and 1931, grouped according to the face colour values of their dams; the number of lambs in each group is shown in brackets.

for 1930 $\sigma = .9558$
for 1931 $\sigma = .9142$

TABLE 7*

Between groups	Year	Difference observed	Difference necessary for significance ±	Group heavier (underlining indicates significance)
A0 and A½	1930	0.656	1.638	A0
	1931	0.537	1.733	A0
A0 and A1	1930	0.49	1.471	A1
	1931	1.781	1.574	$\underline{\text{A1}}$
A0 and A2	1930	1.883	1.442	$\underline{\text{A0}}$
	1931	0.010	1.523	A0
A0 and A3	1930	0.129	1.511	A3
	1931	0.697	1.535	A3
A0 and A4	1930	0.986	1.550	A0
	1931	1.600	1.637	A0
A½ and A1	1930	1.146	1.501	A1
	1931	2.329	1.530	$\underline{\text{A1}}$
A½ and A2	1930	1.227	1.471	A½
	1931	0.527	1.477	A2
A½ and A3	1930	0.785	1.540	A3
	1931	1.234	1.490	A3
A½ and A4	1930	0.230	1.579	A½
	1931	1.062	1.595	A½
A1 and A2	1930	2.373	1.284	$\underline{\text{A1}}$
	1931	1.802	1.287	$\underline{\text{A1}}$
A1 and A3	1930	0.361	1.359	A1
	1931	1.095	1.301	A1
A1 and A4	1930	1.476	1.404	$\underline{\text{A1}}$
	1931	3.391	1.420	$\underline{\text{A1}}$
A2 and A3	1930	2.002	1.328	$\underline{\text{A3}}$
	1931	0.707	1.239	A3
A2 and A4	1930	0.897	1.375	A4
	1931	1.590	1.363	$\underline{\text{A2}}$
A3 and A4	1930	1.110	1.436	A3
	1931	2.297	1.377	$\underline{\text{A3}}$

*Table 7 shows the observed differences in pounds between the various groups and the difference necessary to show statistical significance. $P = .05$.

These results indicate that the belief that the whitest faced ewes are the best milkers is false. But the irregular order into which the six-group fall make it extremely difficult to suggest a satisfactory explanation for the differences. Unless the differences depend on the pattern of the white rather than the quantity of white, and that it happens that a certain

marking or markings, such as a medium-sized tick on the side of the nose or a blaze on the forehead, were sufficiently constant to cause a considerable proportion of them to fall into Groups A1 and A3. (See Figures 10 and 11.)

FIGURE 10. A lamb whose face colours were valued at A1.

FIGURE 11. A lamb whose face colours were valued at A3.

HARDINESS AND FACE COLOUR

Of equal importance but equally difficult to assess is the factor for "hardiness". Some farmers and shepherds believe that hardiness is a character that is inherited from the sire, therefore these data are presented on the basis of the number of lambs which reached one month old compared with the number of matings made by the different face colour classes of rams between 1924 and 1931, involving 2,380 possible matings. Of necessity the adult face colours of the rams had to decide their colour classes as few were bred on the farm.

Hardiness in lambs may be indicated in part by rapidity in gaining their feet after birth and in vigour of suckling, but post-natal activity is influenced by weather conditions to a considerable extent. For example, on a hill farm, more lambs seem to have to be given assistance to suck for the first time on excessively hot or on warm moist days than on clear cool days, moreover active and hardy lambs withstand cold dry winds with little shelter, but cold wet winds soon kill lambs, especially those which do not suckle well. A lambing season generally consists of all types of weather.

It has been assumed that the number of lambs which died of diseases such as "trembling"—which is tick-born, and the number of ewes which were barren or lambed late—and therefore had lambs by an unknown sire, were approximately proportionate for all classes.

No A0 rams were used.

Table 8 shows the influence of the sires, grouped according to face colour, on the hardiness of their lambs.

There seems to be no evidence from these data that hardiness of lambs is correlated with darkness of face of the sire.

FERTILITY

It has been possible to study the influence of 44 rams on the incidence of barrenness of 550 of their daughters and of a few of their grand-daughters.

The amount of barrenness in these ewes varied with their ages and with the favourableness or otherwise of the season; in 1925, 12% of the two-year old ewes were barren; in 1926, 16%; in 1927, 26%; in 1928, 9%; in 1929, 17%; in 1930 and 1931, 28%; and in 1932, 19%; this was an average of almost 20% for the 8 years.

As 3-year old ewes, the average was 15%, and as 4-year olds 14%.

These figures are typical of many Blackface hill flocks of this district. To the west the percentage tends to rise, to the east and south to fall. On a farm in South Argyllshire 33% of the ewes were barren or aborted in 1929–30 (45). Farther south the percentage has been given as 5% (43) and as 5.9% among some 4,000 Blackface ewes, with 1.1% of abortions (41), and in the east of Scotland as 1 to 8% barren with 1 to 5% aborted (36, 37). In the west the rainfall is heavier; a heavy rainfall has been suggested as one of the causes of barrenness and abortion (26, 27). It has been shown in Welsh Mountain sheep (58) that in conditions where barrenness is most common twinning is least common, and many writers have shown that twinning depends on the number of ova which ripen, and, which after fertilization, develop. This, in turn, is considerably influenced by the condition of the ewes before and during mating.

TABLE 8*

Face colour group of ram	Number of rams	Matings	Percentage of matings to lambs raised
			%
A½	2	130	46
A1	6	640	65
A2	9	950	56
A3	5	530	68
A4	4	130	57

*Table 8 shows the effect of the sires, grouped according to face colour, on the hardiness of their lambs.

The sex ratio of reared lambs has been low, 100 females to 88 males. This has been noted before in Blackface sheep (42), and it was suggested that this indicated that lethal factors occur in the breed.

Table 9 shows the breeding results obtained with the daughters and grand-daughters of the 44 rams. The degree of significance of the figures, only considering the 2-year olds, is low. Consideration of older ewes involves reconsidering the same animals; however, these figures are included in the table.

Whether the influence of these rams on the fertility of their daughters is significant may be tested statistically, by setting up the hypothesis that a 100% fertility should be expected; χ^2 then equals, the square of the number barren (x) divided by the number mated $(m) = \frac{x^2}{m}$.

TABLE 9.—THE FERTILITY OF THE F_1 AND F_2 DAUGHTERS OF 44 RAMS*

Ram's No.	Son of ram No.	Years of birth of daughters	No. of 2-year olds		No. as 3-year old or older		No. barren more than once
			Mated	Pregnant	Mated	Pregnant	
7	–	1923	11	11	21	21	0
8	–	1923	7	5	20	18	1
9	–	1923	9	8	29	21	2
551	–	1924–29	97	76	223	200	8
M283	551	1927	1	1	–	–	–
M285	551	1927	5	3	10	8	1
K 6	551	1929	3	3	3	3	–
M106	551	1930	9	7	–	–	–
552	–	1924–26	21	20	58	51	1
553	–	1924–25	34	28	82	72	2
G.W.	–	1925–26	3	2	7	7	–
554	–	1924–26	22	17	63	55	3
555	–	1924	3	3	9	7	–
556	–	1924	2	1	7	7	–
557	–	1924	6	5	18	16	1
558	–	1924–25	15	11	47	44	1
561	–	1925–30	69	59	139	127	2
825	561	1926	2	2	7	6	–
835	561	1926	4	3	12	12	–
840	561	1926	3	3	10	10	–
M282	561	1927	5	4	12	11	–
K 10	561	1929	3	1	2	1	–
562	–	1925	1	0	–	–	–
563	–	1925–30	57	50	97	88	3
564	–	1926	4	4	10	9	–
565	–	1926	2	2	6	6	–
C.N.	–	1926	4	4	13	13	–
566	–	1927–28	14	8	28	22	2
567	–	1927	4	4	7	7	–
568	–	1927–29	29	21	52	41	3
M654	568	1928	2	0	2	2	–
569	–	1927	4	3	11	10	–
M899	–	1928–30	24	23	14	13	–
M897	–	1928	5	2	9	8	1
M896	–	1928	6	4	11	10	–
M895	–	1928	3	2	6	4	1
M894	–	1928	1	1	2	2	–
M893	–	1929	7	3	7	5	1
M891	–	1929–30	8	5	3	3	–
M890	–	1929–30	22	17	11	10	–
M889	–	1930	1	1	–	–	–
M888	–	1930	7	6	–	–	–
M887	–	1930	7	4	–	–	–
M886	–	1930	4	2	–	–	–
Total	–	–	550	439	1,068	950	33

*Rams 563, M106, M890, 551, 561 and 568 are rams A, B, C, D, E, and F of the paper on the inheritance of kemp (9).

It will be seen from Table 10 that the amount of barrenness was not statistically significant whether the 44 rams, the 20 rams which had 6 or more 2-year old daughters or the 12 rams which had 10 or more 2-year old daughters, were considered.

Four grand-daughters of Ram 7 were all pregnant as 2-year olds, but one was barren by a subsequent mating; 8 other matings resulted in pregnancies.

TABLE 10.—χ^2 VALUES FOR TESTING SIGNIFICANCE OF EFFECT OF SIRE ON DAUGHTER'S FERTILITY

No. rams (n)	χ^2	χ^2 necessary for odds of 19 : 1	$\sqrt{2\chi^2} - \sqrt{2n-1}$ *
44	32.6939	–	1.2384
20	22.234	31.410	–
12	16.1253	21.026	–

*When n is greater than 30, the expression $\sqrt{2\chi^2} - \sqrt{2n-1}$ must be greater than 2 for significance, with odds of 19 : 1. (25).

However, 15 grand-daughters of Rams 9, 566 and 568—whose daughters had bad records—only gave 10 pregnancies as 2-year olds, and 7 pregnancies from 11 matings, when older.

Grouping the rams by face colour showed that it has absolutely no influence on fertility.

CONCLUSIONS

The evidence that the Scottish Blackface breed of sheep spread northwards comparatively recently is important because it helps to explain some of the local preferences and local variations of breed characters, especially if the evidence is accepted, that a dun and/or white face breed or breeds was or were established in the country before the spread of the Blackfaces.

It is probable that climate influences Blackface wool types more by affecting the nutritive value of the pastures and the free-living stages of nematodes, than by its direct influence on the fleece.

While the Border Leicester and Wensleydale rams cross excellently with Blackface ewes to produce lambs for butchering, the use of rams of other breeds to improve the Blackface breed has generally been disappointing; however, the increased density of fleeces imparted by Merino blood is interesting.

Face colour depends on at least two, and probably more, allelomorphic genes, with modifiers; generally the face colour of a lamb tends to be midway between that of its parents.

Face colour is important because it is closely correlated with black spotting in the fleeces—comparative absence of black spotting being linked with whiteness of face.

The data presented in this paper do not confirm the belief that blackness of face is correlated with hardiness, or that whiteness of the face of ewes is correlated with a good milking capacity.

The influence of 44 rams on the incidence of barrenness of their daughters has been shown to be not statistically significant.

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A NOTE ON AN EASY CHECK ON MEANS ADJUSTED BY PARTIAL REGRESSIONS[1]

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The design of experimental work at the present time is becoming more complex, and it is not unusual to have several problems under investigation in a single experiment. The need for adjustments of the various treatment means is more necessary as the complexity of the experiment increases. Treatment means are adjusted in order that the various factors under consideration will be on a comparable basis. These adjustments are determined by the partial regressions of the quantity under consideration on the concomitant observations and by the relationship of the observed means to their general mean (1, 2).

The formula for the adjustment of means by partial regression coefficients is:

$$\bar{y} - b_1(\bar{x}_1 - x_1) - b_2(\bar{x}_2 - x_2) \;.\;.\;.\;.\;.\;. -b_n(\bar{x}_n - x_n).$$

where $\bar{y}$ = observed mean of Y, the independent variable,

b_1, b_2, b_n = the partial regressions of Y on X_1, X_2, X_n respectively,

$\bar{x}_1, \bar{x}_2, \bar{x}_n$ = the observed means of X_1, X_2, X_n, the dependent variables respectively, and

x_1, x_2, x_n = the general mean of X_1, X_2, X_n respectively.

Applying this formula for the adjustments of means A, B and C in the following examples:

$$\begin{aligned}
\text{Mean } A &= 20.25 - 0.043(96.46 - 182.07) - (-0.003) \\
&\quad (28.10 - 42.78) - (-0.010)(302.30 - 302.68) \\
&= 20.25 - 0.043\,(-85.61) - (-0.003)(-14.68) - (-0.010) \\
&\quad (-0.38) \\
&= 20\ 25 + 3.6812 - 0.0440 - 0.0038 \\
&= 20.25 + 3.6334 \\
&= 23.8834
\end{aligned}$$

$$\begin{aligned}
\text{Mean } B &= 22.35 - 0.043\,(189.80 - 182.07) - (-0.003)(49.70 - \\
&\quad 42.78) - (-0.010)(303.49 - 302.68) \\
&= 22.35 - 0.043(7.73) - (-0.003)(6.92) - (-0.010)(0.81) \\
&= 22.35 - 0.3324 + 0.0207 + 0.0081 \\
&= 22.35 - 0.3036 \\
&= 22.0464
\end{aligned}$$

$$\begin{aligned}
\text{Mean } C &= 30.36 - 0.043\,(259.95 - 182.07) - (-0.003)(50.54 - \\
&\quad 42.78) - (-0.010)(302.25 - 302.68) \\
&= 30.36 - 0.043(77.88) - (-0.003)(7.76) - (-0.010)(-0.43) \\
&= 30.36 - 3.3488 + 0.0233 - 0.0043 \\
&= 30.36 - 3.3298 \\
&= 27.0302
\end{aligned}$$

[1] Contribution from the Poultry Division, Experimental Farms Service, Dominion Department of Agriculture, Ottawa.

[2] Agricultural Assistant.

From these examples it will be seen that when the treatment means are adjusted to the general mean of the concomitant observations, the sum of adjustments must be zero. This provides a check on the correctness of the individual adjustments. Since the sum of the adjustments must be zero, it follows that the sum of the adjusted means must equal the sum of the unadjusted. For example, the sum of the adjusted means is

$(23.8834 + 22.0464 + 27.0302) = 72.96$ and the sum of the unadjusted means is $(20.25 + 22.35 + 30.36) = 72.96$.

Thus it is possible to check on the internal consistency of means adjusted by this method, although not of the correctness of the coefficients b_1, b_2, etc.

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THE EFFECT OF AGE ON THE VITALITY OF SOYBEAN SEED[1]

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Does the age of soybean seed affect its power to germinate? This question has been asked by some farmers who took a chance on sowing seed of unknown age and were disappointed with the stand of plants. It is not likely that much old seed will be sown, but if there is a risk in so doing it should be known so that even the occasional loss may be avoided. Therefore, this study was undertaken to get information on the germination of soybean seed from one to eight years old. The work was outlined by the Department of Field Husbandry, Ontario Agricultural College; it commenced in 1936 and continued for three years.

Eight samples of O.A.C. No. 211 soybean seed were used for the 1936 test. One of them had been grown in each of the years 1928 to 1935 inclusive. Two germination tests were made with each sample. The first test was carried out in the field under normal growing conditions, and the second test, with another portion of each sample, was made in the germination room of the Field Husbandry building, where the seed was planted in boxes of sand.

Table 1.—The average germination of soybean seed in all tests over the three year period 1936–38

Seed used	3 Field Tests germination %	7 Indoor Tests germination %
One year old—Previous year's crop	89.6	98.0
Two years old	63.3	93.7
Three years old	65.6	96.0
Four years old	36.6	76.8
Five years old	8.0	61.4
Six years old	5.0	25.7
Seven years old	1.6	20.8
Eight years old	0	0

For the field test eight rows twenty-eight inches apart were laid out and one hundred seeds planted in each row with four inch spaces between the seeds. As soon as the plants appeared above ground they were counted daily until no more came up.

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Eight boxes of sand were used for the indoor test and fifty seeds were planted in each box. The boxes were kept in a warm room and watered when necessary. From the time the plants began to come up they were counted daily. Controlled heat and moisture gave a higher germination than that obtained in the field. This work was repeated in 1937 and in 1938 with a different set of samples each year.

A further germination test, using thirty-six samples of soybean seed, four of them having been produced in each of the years 1930 to 1937, was made at the end of 1938. Twenty-five seeds of each sample were planted in boxes of sand on December 28th, 1938, and the plants began to come up on January 3, 1939. Table I summarizes the results of these tests.

CONCLUSIONS

If soybean seed is not more than 3 years old it will germinate satisfactorily although there is a slight advantage in favour of new seed. Four year old seed showed considerable weakness, while anything older than that was so low in vitality as to be unfit for sowing. The few plants that grew from 5 and 6 year old seed were weak and slow in coming up. Eight year old seed failed to produce a single plant.

Good looking soybean seed can be very disappointing as far as germination is concerned. Its age cannot be determined by sight and the only safe plan for growers to follow is to know the year in which the seed they intend sowing was produced, or to make a germination test. Nothing short of a high indoor test should be considered satisfactory because the field germination with less favourable conditions will not likely be as great.

DIGESTIBILITY STUDIES WITH RUMINANTS*

VI. Associative Digestibility of Grains: Barley, Oats and Oil Cake

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(Received for publication September 27, 1939)

In a previous paper (1) a study was made of the "associative digestibilities" of corn silage, oat straw, oat hulls, hay and mangels. When fed in various combinations to cattle, the roughages, hay, corn silage, oat straw and mangels, had the same values for the digestibility of the non-nitrogen fraction as when each was fed alone. The digestibility of the nitrogen compounds in the combinations was different from that when these feeds formed the sole ration. Protein, however, constitutes a relatively small amount of such feeding stuffs so that the total feed value was unaffected by association. The digestibility of the oat hulls when fed alone was higher than when calculated from a ration with either hay or corn silage.

In the present paper, data are presented on the associative digestibility among barley, oats and oil cake.

Seven grade Shorthorn steers, numbered 1 to 7, were used. Their mean weights were, respectively, 602, 592, 638, 591, 516, 539, and 420 kilogrammes. Animals 1 to 4 were $3\frac{1}{2}$ years old at the start of the digestion trials and animals 5, 6 and 7 were $2\frac{1}{2}$ years old.

The following 6 rations were studied:—

(a) Hay
(b) Hay + barley
(c) Hay + oats
(d) Hay + oil cake meal
(e) Hay + barley + oats
(f) Hay + barley + oats + oil cake meal.

The experiment was set up in the form of a 6 × 6 randomized Latin square using 6 animals (numbers 2–7, inclusive) in 6 periods. Difficulties encountered during the experiment prevented the completion of the Latin square as originally scheduled. One of these difficulties was the refusal of feed on a number of occasions by the animals. Another was the fact that the composition and digestibility of the hay changed suddenly at Period 5. Timothy hay was used in the experiment, the botanical analysis of which is given in Table 1. As far as could be determined when storing, the entire lot of hay was the same. Evidently, however, either two different stages of maturity were represented in the crop or else, through cultural or climatic conditions, there was a difference in the degree of development. At the time the change was discovered, the hay had been all cut for the trials and a second botanical analysis was impossible.

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TABLE 1.—BOTANICAL ANALYSIS OF HAY

Species	Per cent
Timothy	79.5
Alfalfa	11.9
Kentucky blue grass	4.9
Canadian blue grass, nerved manna grass, etc.	traces
Red top	2.9
Couch grass	0.4
Weeds	0.4

The definite nature of the change in composition and digestibility is shown in Table 2. As far as the chemical composition was concerned, significant changes occurred for the organic matter, ether extract, crude fibre and nitrogen-free extract. In the same way there were significant differences in the digestibility of the organic matter, ether extract, crude fibre and nitrogen-free extract. In calculating the coefficients of digestibility of the single grains or grain mixtures in periods 1 to 4, inclusive, the mean values of the coefficients of the hay for those periods were used. Similarly, the coefficients in periods 5, 6 and 7, were obtained from the mean values for the hay in those periods.

TABLE 2.—COMPARISON OF HAY IN PERIODS 1 TO 4, INCLUSIVE, WITH HAY IN PERIODS 5 TO 7, INCLUSIVE, ON BASIS OF CHEMICAL COMPOSITION AND DIGESTIBILITY*

Nutrient	Composition of dry matter in per cent		Coefficients of digestibility in per cent		
	Periods 1–4 (16 values)	Periods 5–7 (12 values)	Periods 1–4 (5 values)	Periods 5–7 (3 values)	*t* value† for difference
Organic matter	95.42 ± 0.04	93.42 ± 0.06	49.6	55.6	5.755
Nitrogen	1.17 ± 0.01	1.13 ± 0.02	43.6	48.6	1.741
Ether extract	1.83 ± 0.03	2.65 ± 0.04	43.5	51.8	5.890
Crude fibre	40.24 ± 0.22	36.13 ± 0.14	48.4	54.0	3.880
N-free extract	46.07 ± 0.21	47.57 ± 0.14	51.8	58.2	5.173

* Mean values only are given.
† Necessary value at P of 0.05 = 2.447.
Necessary value at P of 0.01 = 3.143.

In view of these difficulties which were encountered, more values than originally planned were obtained by including another period, namely, period 7, and another animal, namely, animal No. 1.

The feeding schedule as finally set up is given in Table 3. Footnotes have been used to indicate where food refusals occurred. It will be noted that single grains or grain mixtures were fed at the same level in all cases. Two exceptions occurred in periods 5 and 6 with animal No. 7. This animal showed indifferent food consumption in the corresponding preliminary periods and it was thought advisable to reduce the grain. The hay was correspondingly reduced.

In the cases of the barley-oats combination and the barley-oats-oil cake combination, slight adjustments were made in the weights fed in

TABLE 3.—FEEDING SCHEDULE

Period	Feed	Daily rations in kilogrammes						
		Animal 1	Animal 2	Animal 3	Animal 4	Animal 5	Animal 6	Animal 7
1	Hay	–	7.0	5.0	5.0	5.0*	5.0	5.0
	Barley	–	–	–	3.0	1.5	–	1.0
	Oats	–	–	–	–	1.5	3.0	1.0
	Oil cake	–	–	3.0	–	–	–	1.0
2	Hay	–	4.5	7.0	4.5	4.5**	4.5	4.5
	Barley	–	1.5	–	1.0	–	3.0	–
	Oats	–	1.5	–	1.0	3.0	–	–
	Oil cake	–	–	–	1.0	–	–	3.0
3	Hay	–	4.5	4.5	4.5	4.5	7.0†	4.5††
	Barley	–	–	3.0	–	1.0	–	1.5
	Oats	–	–	–	3.0	1.0	–	1.5
	Oil cake	–	3.0	–	–	1.0	–	–
4	Hay	–	4.5	4.5	4.5	4.5	4.5	5.0
	Barley	–	1.0	–	1.5	3.0	–	–
	Oats	–	1.0	3.0	1.5	–	–	–
	Oil cake	–	1.0	–	–	–	3.0	–
5	Hay	4.5	4.5	4.5	4.5	6.0‡	4.5	4.0
	Barley	1.5	3.0	1.0	–	–	1.5	–
	Oats	1.5	–	1.0	–	–	1.5	2.5
	Oil cake	–	–	1.0	3.0	–	–	–
6	Hay	4.5	4.5	4.5	7.0	4.5	4.5	4.0
	Barley	1.0	–	1.5	–	–	1.0	2.5
	Oats	1.0	3.0	1.5	–	–	1.0	–
	Oil cake	1.0	–	–	–	3.0	1.0	–
7	Hay	7.0	4.5	4.5	7.0	–	–	–
	Barley	–	1.5	–	–	–	–	–
	Oats	–	1.5	–	–	–	–	–
	Oil cake	–	–	3.0	–	–	–	–

* Daily ration not given on seventh day of collection period.
** Refused feed completely after eighth day, collection period of eight days only.
† One-half daily ration given on sixth day of collection period; refused 310 grams.
†† Complete feed refusal, removed from trial.
‡ Refused 229 grams, 5.0 kilogrammes fed on seventh day of collection period.

TABLE 4.—ADJUSTMENTS MADE IN QUANTITIES OF OATS AND OIL CAKE FED TO MAINTAIN CONSTANT DRY MATTER RATIOS WITH BARLEY

Period	Animal	Amount added in grams	
		Oats	Oil cake
2	2	101	–
	4	67	48
3	5	48	93
4	4	78	–
	2	51	56
5	6	148	–
	3	99	181
6	3	162	–
	1 and 6	107	200
7	2	29	–

TABLE 5.—COEFFICIENTS OF DIGESTIBILITY IN PERCENT AND TOTAL DIGESTIBLE NUTRIENTS OF INDIVIDUAL FEEDS AND MIXTURES

(All values calculated from mixed rations with hay)

Period	Barley	Oats	Oil cake	Barley-oats mixture		Barley-oats-oil cake mixture	
				Found	Calculated	Found	Calculated
Dry matter coefficients							
1	81.5	66.6	69.3	—*	74.0	69.8†	72.3
2	77.0	66.5	71.5	74.7	71.7	74.1	71.6
3	81.0	67.6	70.2	—**	74.2	75.1	72.8
4	77.0	66.6	74.3	71.3	71.7	73.8	72.6
5	76.0	64.1	71.5	67.4	70.0	72.4	70.5
				74.0			
6	74.3	63.4	68.8	68.6	68.8	69.7	68.8
						72.0	
7	—	—	71.5	69.4	—	—	—
Means	77.8	65.8	71.0	70.9	71.7	72.4	71.4
t values‡				0.536		0.965	
Organic matter coefficients							
1	83.8	68.3	72.7	—*	76.0	71.3†	74.8
2	79.5	68.3	73.8	76.7	73.8	77.1	73.8
3	83.8	68.9	72.9	—**	76.3	77.2	75.1
4	78.5	68.9	77.1	73.3	73.7	76.1	74.8
5	78.0	66.1	74.1	76.3	72.0	74.9	72.7
				69.4			
6	76.2	65.1	71.8	70.7	70.6	71.9	71.0
						74.6	
7	—	—	74.6	71.5	—	—	—
Means	80.0	67.6	73.9	73.0	73.7	74.7	73.7
t values‡				0.459		0.878	
Nitrogen coefficients							
1	80.8	72.3	84.1	—*	76.8	80.4†	81.1
2	71.3	74.0	84.2	75.4	72.5	80.8	79.4
3	76.9	78.2	83.5	—**	77.6	79.1	81.0
4	72.0	74.5	83.5	70.3	73.3	80.4	79.2
5	75.4	74.6	84.3	71.3	75.0	80.6	80.5
				75.5			
6	74.3	73.4	83.0	72.9	73.9	77.7	79.3
						79.9	
7	—	—	83.8	73.9	—	—	—
Means	75.1	74.5	83.8	73.2	74.9	79.8	80.1
t values‡				1.421		0.535	

t for barley-oats mixture = 2.228 at P of 0.05.

t for barley-oats-oil cake mixture = 2.201 at P. of 0.05.

* Values for Animal 7 not included in these calculations as explained in text.

** Digestion trial not completed.

† Values for Animal 5 somewhat questionable as explained in text.

‡ t values given for difference between mean "found" and "calculated" values for the two mixtures.

Table 5.—Coefficients of digestibility in percent and total digestible nutrients of individual feeds and mixtures—*Continued*

(All values calculated from mixed rations with hay)

Period	Barley	Oats	Oil cake	Barley-oats mixture		Barley-oats-oil cake mixture	
				Found	Calculated	Found	Calculated
				Ether extract coefficients			
1	29.8	89.9	95.7	–*	80.6	94.7†	91.7
2	43.0	90.4	96.4	84.9	80.4	95.0	92.3
3	15.9	72.5	95.6	–**	53.0	90.4	87.6
4	21.1	75.7	95.6	51.1	61.8	93.1	90.6
5	19.5	69.8	93.8	70.2	58.0	86.9	86.1
				59.3			
6	49.3	87.2	95.8	74.7	80.6	85.3	91.5
						94.0	
7	–	–	92.4	72.2	–	–	–
Means	29.8	80.9	95.0	68.7	69.1	91.3	90.0
t values‡				0.056		0.699	
				Nitrogen-free extract coefficients			
1	90.5	75.6	75.6	–*	83.4	80.9†	81.4
2	88.5	75.1	80.0	82.9	82.1	84.3	81.6
3	90.2	78.0	79.2	–**	84.3	85.6	83.0
4	88.4	77.1	83.0	82.5	83.0	84.5	83.0
5	87.4	74.5	80.7	79.0	81.2	83.2	81.1
				83.3			
6	85.4	74.8	77.5	80.9	80.3	81.9	79.6
						80.4	
7	–	–	79.6	80.8	–	–	–
Means	88.4	75.9	79.4	81.6	82.4	82.9	81.6
t values‡				0.891		1.407	
				Total carbohydrates coefficients			
1	84.8	67.4	62.9	–*	76.0	67.1†	72.6
2	80.8	66.0	62.5	75.9	73.4	74.7	70.7
3	84.9	67.1	64.0	–**	75.8	75.6	72.8
4	79.3	67.5	71.2	73.6	73.3	73.7	72.8
5	78.5	64.2	65.3	67.8	71.3	73.1	69.7
				76.2			
6	76.0	62.0	60.8	69.7	68.9	72.6	66.8
						68.2	
7	–	–	66.9	70.8	–	–	–
Means	80.7	65.7	64.8	72.3	73.1	72.1	70.9
t values‡				0.448		0.748	

t for barley-oats mixture = 2.228 at *P* of 0.05.
t for barley-oats-oil cake mixture = 2.201 at *P*. of 0.05.
* Values for Animal 7 not included in these calculations as explained in text.
** Digestion trial not completed.
† Values for Animal 5 somewhat questionable as explained in text.
‡ *t* values given for difference between mean "found" and "calculated" values for the two mixtures.

TABLE 5.—COEFFICIENTS OF DIGESTIBILITY IN PERCENT AND TOTAL DIGESTIBLE NUTRIENTS OF INDIVIDUAL FEEDS AND MIXTURES—*Concluded*
(All values calculated from mixed rations with hay)

Period	Barley	Oats	Oil cake	Barley-oats mixture		Barley-oats-oil cake mixture	
				Found	Calculated	Found	Calculated
T.D.N. in per cent dry matter							
1				—*	76.2	76.6†	80.2
2				76.4	73.8	82.8	79.3
3				—**	74.1	79.9	77.9
4				71.1	71.4	78.7	77.5
5				67.6 74.6	70.4	78.4	75.9
6				70.0	69.8	77.5 75.7	74.3
7				71.2	—	—	—
Means				71.8	72.6	78.5	77.5
t values‡				0.485		0.794	

t for barley-oats mixture = 2.228 at *P* of 0.05.
t for barley-oats-oil cake mixture = 2.201 at *P*. of 0.05.
* Values for Animal 7 not included in these calculations as explained in text.
** Digestion trial not completed.
† Values for Animal 5 somewhat questionable as explained in text.
‡ *t* values given for difference between mean "found" and "calculated" values for the two mixtures.

order to maintain a constant ratio of the dry matters for each combination throughout the experiment. The actual weights involved were quite small as shown in Table 4. The adjustments were made on the first day of the collection period.

Each period consisted of 24 days, 12 of which were preliminary and 12 of which were collection. During the intervening 4 days between each period, the animals were given exercise and the following ration: corn silage—10 kilogrammes, hay—5 kilogrammes, and grain mixture—3 kilogrammes. During the preliminary period iodized rock salt was given ad libitum and during the collection period 30 grams of granulated iodized salt were given per animal per day.

The complete experimental data are given in Tables 6 and 7 in the Appendix. A summary of the coefficients of digestibility and the total digestible nutrients is given in Table 5. All data represent coefficients calculated from a mixture in which hay was the basal ration. For the "calculated"[1] values of the barley-oats mixture and the barley-oats-oil cake mixture in any period, the values of the individual grains for that period were used. The significance of the differences between the "found" and the "calculated" values was determined by Fisher's *t* test.

DISCUSSION OF RESULTS

Dry Matter and Organic Matter

The results for the dry matter and organic matter were similar. The mean "found" values for the barley-oats mixture were less than one

[1] "Calculated" values of the combinations were obtained additively from the values of the individual grains. "Found" values of the combinations were those actually obtained in digestion trials.

absolute per cent lower than the "calculated" values, whereas the mean "found" values for the barley-oats-oil cake mixture were one absolute per cent higher than the "calculated". These differences were not significant.[1]

There are, however, certain qualifications to this conclusion. In the first place, in period 1 with the barley-oats mixture, difficulty was encountered in the feed consumption as the following record shows. Commencing from December 6th, 1937, Animal 5 on this combination was continually refusing some feed until on December 12th it was necessary to remove an entire ration. From then until the end of the period on December 17th, consumption was irregular. The animal, however, completed the period with all the remaining feed cleaned up. The coefficients of digestibility for the dry matter and organic matter were, respectively, 62.2% and 63.0%. These were far out of line with the remaining values and were not included in the calculations presented above. Further calculations were, therefore, made including these values. The mean "found" values for the dry matter and organic matter now became 69.7% and 71.6%. The differences between the "found" and "calculated" coefficients were still not significant.

In the second place, animal 7 on the barley-oats-oil cake mixture in period 1 also refused feed at the beginning of the collection period and it was necessary to remove a complete ration at the same time as the removal was made from animal 5. The values, however, were in line with the remaining ones for this combination and have been included in the calculations. It would be inconsistent, nevertheless, to differentiate between the two cases of animal 5 and animal 7 solely on their agreement or non-agreement with the remaining values. For that reason, the significance of the differences between the "found" and "calculated" values for the barley-oats-oil cake mixture has been recalculated omitting the "found" values for period 1. When this was done, the mean "found" values for the dry matter and organic matter were, respectively, 72.9% and 75.3%, that is, slightly higher than the ones given in Table 5. Fisher's t test revealed no significant difference between the means.

Finally, the variance within the groups included any variance due to the period. To allow for this, it might be justifiable to examine the groups by means of a series of differences between corresponding values in the same period. In the case of the barley-oats mixture, only 4 such comparisons were available, namely, periods 2, 4, 5 and 6. Moreover, in period 5 two values were averaged. This lessened the value of the comparison. In the case of the barley-oats-oil cake mixture, 6 values were available when period 1 was included, and 5 when it was omitted. As in the case of the barley-oats mixture, 2 values for one of the periods (period 6) were averaged. Calculations have been made to cover all these situations.

In the case of the barley-oats mixture, there were no significant differences between the "found" and "calculated" values. In the case of the barley-oats-oil cake mixture there were no significant differences when the values for period 1 were included. When, however, these values were omitted, the differences were significant. It was concluded that there was definitely no associative effect between barley and oats as far as dry

[1] In this paper, significance is determined at 5% points.

matter and organic matter were concerned. With the barley-oats-oil cake mixture, the possibility could not be excluded that there was a small effect to the order of 1 or 2%.

Nitrogen

There were no significant differences in the coefficients of digestibility of nitrogen between the "found" and "calculated" values for either the barley-oats mixture or the barley-oats-oil cake mixture. The inclusion of the "found" values for the barley-oats mixture for period 1 or the exclusion of the same values for the barley-oats-oil cake mixture in period 1, did not affect the results.

Ether Extract

The variation in the ether extract was quite large indeed. However, the mean "found" and "calculated" values for the barley-oats mixture and the barley-oats-oil cake mixture showed close agreement. This variation was mainly caused by the oats. The ether extract in this feed varied from 1.53% to 4.30% of the dry matter during different periods, resulting in variable values of the coefficients of digestibility. The values for the barley also showed considerable fluctuation due to the small amount of ether extract.

Nitrogen-free Extract

The remarks made concerning the dry matter and the organic matter are equally applicable to the nitrogen-free extract. The mean "found" value of the barley-oats mixture was slightly less than the "calculated", and the mean "found" value for the barley-oats-oil cake mixture was slightly greater than the "calculated". These conclusions were the same whether or not the questionable values referred to previously were included or excluded. As with the dry matter or the organic matter when the statistical analysis was made by means of differences, there was no significant difference between the mean values of the barley-oats mixture but there was a significant difference in the case of the barley-oats-oil cake mixture. Again, therefore, the fact cannot be excluded that with the addition of oil cake there may be an increase in digestibility of about 1%.

Total Carbohydrates

It was not possible to obtain satisfactory coefficients for crude fibre. In order, therefore, to include this nutrient, the coefficients of digestibility of the total carbohydrates (crude fibre + nitrogen-free extract) have been given. There were no significant differences between the "found" and "calculated" mean values for either the barley-oats mixture or the barley-oats-oil cake mixture. As before, however, by using the method of differences it was possible to get a significant difference between the mean "calculated" and "found" values for the barley-oats-oil cake mixture.

Total Digestible Nutrients

There was no significant difference between the "found" and "calculated" values for either the barley-oats or barley-oats-oil cake combinations. A significant difference could, however, be obtained for the barley-oats-oil cake combination when the method of differences was used.

SUMMARY AND CONCLUSIONS

Using grade Shorthorn steers as experimental animals, the coefficients of digestibility of barley, oats, oil cake, barley + oats, and barley + oats + oil cake were determined using hay as the basal ration.

The values found for the barley-oats mixture and the barley-oats-oil cake mixture were compared with the values calculated for these mixtures from the digestibilities of the individual feeds.

It was concluded that there was no associative effect between barley and oats.

In the case of the barley-oats-oil cake combination, there was no associative effect as far as protein and ether extract were concerned. Due to certain experimental difficulties as discussed in the text, however, the conclusion could not be excluded that the digestibilities of dry matter, organic matter and carbohydrates as "found", might have been about 1 to 2% higher than the digestibilities as "calculated". In any case, if there were a real difference, it was of small magnitude.

ACKNOWLEDGMENT

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REFERENCES

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APPENDIX

Table 6—Chemical composition of feeding stuffs in per cent.

Feed	Period	Original moisture	On dry matter basis				
			Ash	* Protein	Ether extract	Crude Fibre	N-free extract
Hay	1	13.24	4.47	7.48	1.94	40.72	45.39
	2	13.00	4.48	6.93	1.82	40.74	46.03
	3	13.08	4.74	7.42	1.79	39.67	46.38
	4	12.68	4.65	7.29	1.77	39.84	46.45
	4†	12.46	4.95	8.19	1.88	40.03	44.95
	5‡	13.19	6.48	7.61	2.53	35.92	47.46
	6	12.17	6.70	7.05	2.78	36.10	47.37
	7	11.39	6.56	6.56	2.62	36.37	47.89
Refused hay	5	9.73	24.16	10.75	2.13	25.52	37.44
Barley	1	15.82	3.50	13.13	0.80	6.94	75.63
	2	15.42	3.38	12.74	1.13	6.41	76.34
	3	15.60	3.32	12.94	0.95	6.53	76.26
	4	15.73	3.36	12.96	0.53	6.75	76.40
	5	15.38	3.23	12.93	0.79	6.71	76.34
	6	15.13	3.14	12.76	0.79	6.61	76.70
	7	15.17	3.12	13.16	0.77	5.57	77.38
Oats	1	13.88	3.27	11.40	4.30	13.91	67.12
	2	13.96	3.16	12.06	4.13	12.06	68.59
	3	14.00	3.37	11.23	1.75	13.94	69.71
	4	14.16	3.67	11.37	1.53	14.64	68.79
	5	14.14	3.26	11.59	2.53	12.98	69.64
	6	13.95	3.26	11.10	3.57	13.71	68.36
	7	13.36	3.23	11.17	3.98	13.80	67.82
Oil cake meal	1	7.82	5.67	28.28	13.00	8.66	44.39
	2	7.75	5.71	29.47	14.07	8.33	42.42
	3	8.29	5.92	30.02	10.84	8.97	44.25
	4	8.15	5.90	29.30	11.00	8.77	45.03
	5	8.72	5.77	29.56	11.18	8.47	45.02
	6	8.60	5.93	29.58	10.67	8.61	45.21
	7	8.23	6.04	29.38	9.79	9.76	45.03

* Hay protein = N × 6.25
Barley protein = N × 5.83
Oats protein = N × 5.83
Oil cake protein = N × 5.30
† Animal 7 only.
‡ For animal 5 only, composition was as in period 4.

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PER CENT.)

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
PERIOD 1								
Animal No. 2								
In hay	84.000	72.878	69.620	0.872	1.414	29.676	33.079	62.755
In feces	165.679	38.466	35.850	0.473	0.758	15.767	16.317	32.084
Digested		34.412	33.770	0.399	0.656	13.909	16.762	30.671
Coefficient		47.2	48.5	45.8	46.4	46.9	50.7	48.9
Animal No. 3								
In hay	60.000	52.056	49.729	0.623	1.010	21.197	23.628	44.825
In oil cake	36.000	33.185	31.303	1.770	4.314	2.874	14.731	17.605
Total ration	96.000	85.241	81.032	2.393	5.324	24.071	38.359	62.430
In feces	181.195	37.087	33.612	0.633	0.757	13.882	14.983	28.865
Digested		48.154	47.420	1.760	4.567	10.189	23.376	33.565
Dig. from hay		25.143	24.666	0.272	0.439	10.259	12.239	22.498
Dig. from oil cake		23.011	22.754	1.488	4.128	−0.070	11.137	11.067
Coeff. of oil cake		69.3	72.7	84.1	95.7	−2.4	75.6	62.9
Animal No. 4								
In hay	60.000	52.056	49.729	0.623	1.010	21.197	23.628	44.825
In barley	36.000	30.305	29.244	0.682	0.242	2.103	22.920	25.023
Total ration	96.000	82.361	78.973	1.305	1.252	23.300	46.548	69.848
In feces	145.433	32.519	29.794	0.482	0.741	12.585	13.557	26.142
Digested		49.842	49.179	0.823	0.511	10.715	32.991	43.706
Dig. from hay		25.143	24.666	0.272	0.439	10.259	12.239	22.498
Dig. from barley		24.699	24.513	0.551	0.072	0.456	20.752	21.208
Coeff. of barley		81.5	83.8	80.8	29.8	21.7	90.5	84.8
Animal No. 5								
In hay	55.000	47.718	45.585	0.571	0.926	19.431	21.659	41.090
In barley	16.500	13.890	13.404	0.313	0.111	0.964	10.505	11.469
In oats	16.500	14.210	13.745	0.278	0.611	1.977	9.538	11.515
Total grain	33.000	28.100	27.149	0.591	0.722	2.941	20.043	22.984
Total ration	88.000	75.818	72.734	1.162	1.648	22.372	41.702	64.074
In feces	169.585	35.304	33.013	0.517	0.688	13.864	15.294	29.158
Digested		40.514	39.721	0.645	0.960	8.508	26.408	34.916
Dig. from hay		23.048	22.610	0.249	0.403	9.405	11.219	20.624
Dig. from grain		17.466	17.111	0.396	0.557	−0.897	15.189	14.292
Coeff. of grain		62.2	63.0	67.0	77.1	−30.5	75.8	62.2
Animal No. 6								
In hay	60.000	52.056	49.729	0.623	1.010	21.197	23.628	44.825
In oats	36.000	31.003	29.989	0.606	1.333	4.313	20.809	25.122
Total	96.000	83.059	79.718	1.229	2.343	25.510	44.437	69.947
In feces	158.373	37.282	34.572	0.519	0.705	14.070	16.456	30.526
Digested		45.777	45.146	0.710	1.638	11.440	27.981	39.421
Dig. from hay		25.143	24.666	0.272	0.439	10.259	12.239	22.498
Dig. from oats		20.634	20.480	0.438	1.199	1.181	15.742	16.923
Coeff. of oats		66.6	68.3	72.3	89.9	27.4	75.6	67.4
Animal No. 7								
In hay	55.000	47.718	45.585	0.571	0.926	19.431	21.659	41.090
In barley	11.000	9.260	8.936	0.209	0.074	0.643	7.003	7.646
In oats	11.000	9.473	9.163	0.185	0.407	1.318	6.358	7.676
In oil cake	11.000	10.140	9.565	0.541	1.318	0.878	4.501	5.379
Total grain	33.000	28.873	27.664	0.935	1.799	2.839	17.862	20.701
Total ration	88.000	76.591	73.249	1.506	2.725	22.270	39.521	61.791
In feces	157.765	33.385	30.918	0.505	0.618	13.434	13.845	27.279
Digested		43.206	42.331	1.001	2.107	8.836	25.676	34.512
Dig. from hay		23.048	22.610	0.249	0.403	9.405	11.219	20.624
Dig. from grain		20.158	19.721	0.752	1.704	−0.569	14.457	13.888
Coeff. of grain		69.8	71.3	80.4	94.7	−20.0	80.9	67.1

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PER CENT.)—*Continued*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
PERIOD 2								
Animal No. 2								
In hay	54.000	46.980	44.875	0.521	0.855	19.140	21.625	40.765
In barley	18.000	15.224	14.709	0.333	0.172	0.976	11.622	12.598
In oats	18.101	15.574	15.082	0.322	0.643	1.878	10.682	12.560
In total grain	36.101	30.798	29.791	0.655	0.815	2.854	22.304	25.158
In total ration	90.101	77.778	74.666	1.176	1.670	21.994	43.929	65.923
In feces	136.722	32.072	29.551	0.455	0.606	12.110	14.243	26.353
Digested		45.706	45.115	0.721	1.064	9.884	29.686	39.570
Dig. from hay		22.691	22.258	0.227	0.372	9.264	11.202	20.466
Dig. from grain		23.015	22.857	0.494	0.692	0.620	18.484	19.104
Coeff. of grain		74.7	76.7	75.4	84.9	21.7	82.9	75.9
Animal No. 3								
In hay	84.000	73.080	69.806	0.810	1.330	29.773	33.639	63.412
In feces	189.118	38.527	35.973	0.469	0.759	15.927	16.497	32.424
Digested		34.553	33.833	0.341	0.571	13.846	17.142	30.988
Coefficient		47.3	48.5	42.1	42.9	46.5	51.0	48.9
Animal No. 4								
In hay	54.000	46.980	44.875	0.521	0.855	19.140	21.625	40.765
In barley	12.000	10.150	9.807	0.222	0.115	0.651	7.749	8.400
In oats	12.067	10.382	10.054	0.215	0.429	1.252	7.121	8.373
In oil cake	12.048	11.114	10.479	0.617	1.564	0.926	4.715	5.641
In total grain	36.115	31.646	30.340	1.054	2.108	2.829	19.585	22.414
In total ration	90.115	78.626	75.215	1.575	2.963	21.969	41.210	63.179
In feces	191.968	32.474	29.568	0.496	0.588	12.477	13.503	25.980
Digested		46.152	45.647	1.079	2.375	9.492	27.707	37.199
Dig. from hay		22.691	22.258	0.227	0.372	9.264	11.202	20.466
Dig. from grain		23.461	23.389	0.852	2.003	0.228	16.505	16.733
Coeff. of grain		74.1	77.1	80.8	95.0	8.1	84.3	74.7
*Animal No. 5**								
In hay	36.000	31.320	29.917	0.347	0.570	12.760	14.417	27.177
In oats	24.000	20.650	19.997	0.427	0.853	2.490	14.164	16.654
In total ration	60.000	51.970	49.914	0.774	1.423	15.250	28.581	43.831
In feces	104.384	23.106	21.408	0.307	0.404	8.716	10.472	19.188
Digested		28.864	28.506	0.467	1.019	6.534	18.109	24.643
Dig. from hay		15.128	14.839	0.151	0.248	6.176	7.468	13.644
Dig. from oats		13.736	13.667	0.316	0.771	0.358	10.641	10.999
Coeff. of oats		66.5	68.3	74.0	90.4	14.4	75.1	66.0
Animal No. 6								
In hay	54.000	46.980	44.875	0.521	0.855	19.140	21.625	40.765
In barley	36.000	30.449	29.420	0.666	0.344	1.952	23.245	25.197
In total ration	90.000	77.429	74.295	1.187	1.199	21.092	44.870	65.962
In feces	128.862	31.285	28.645	0.485	0.679	12.032	13.105	25.137
Digested		46.144	45.650	0.702	0.520	9.060	31.765	40.825
Dig. from hay		22.691	22.258	0.227	0.372	9.264	11.202	20.466
Dig. from barley		23.453	23.392	0.475	0.148	−0.204	20.563	20.359
Coeff. of barley		77.0	79.5	71.3	43.0	−10.5	88.5	80.8
Animal No. 7								
In hay	54.000	46.980	44.875	0.521	0.855	19.140	21.625	40.765
In oil cake	36.000	33.210	31.314	1.843	4.673	2.766	14.088	16.854
In total ration	90.000	80.190	76.189	2.364	5.528	21.906	35.713	57.619
In feces	155.475	33.768	30.823	0.585	0.652	13.379	13.240	26.619
Digested		46.422	45.366	1.779	4.876	8.527	22.473	31.000
Dig. from hay		22.691	22.258	0.227	0.372	9.264	11.202	20.466
Dig. from oil cake		23.731	23.108	1.552	4.504	−0.737	11.271	10.534
Coeff. of oil cake		71.5	73.8	84.2	96.4	−26.6	80.0	62.5

* Collection period of 8 days for this animal.

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PER CENT.)—*Continued*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
PERIOD 3								
Animal No. 2								
In hay	54.000	46.937	44.712	0.557	0.840	18.620	21.769	40.389
In oil cake	36.000	33.016	31.061	1.870	3.579	2.962	14.610	17.572
In total ration	90.000	79.953	75.773	2.427	4.419	21.582	36.379	57.961
In feces	165.917	34.108	30.967	0.623	0.634	12.896	13.531	26.427
Digested		45.845	44.806	1.804	3.785	8.686	22.848	31.534
Dig. from hay		22.671	22.177	0.243	0.365	9.012	11.276	20.288
Dig. from oil cake		23.174	22.629	1.561	3.420	−0.326	11.572	11.246
Coeff. of oil cake		70.2	72.9	83.5	95.6	−11.0	79.2	64.0
Animal No. 3								
In hay	54.000	46.937	44.712	0.557	0.840	18.620	21.769	40.389
In barley	36.000	30.384	29.375	0.674	0.289	1.984	23.171	25.155
In total ration	90.000	77.321	74.087	1.231	1.129	20.604	44.940	65.544
In feces	167.035	30.031	27.301	0.470	0.718	11.138	12.772	23.910
Digested		47.290	46.786	0.761	0.411	9.466	32.168	41.634
Dig. from hay		22.671	22.177	0.243	0.365	9.012	11.276	20.288
Dig. from barley		24.619	24.609	0.518	0.046	0.454	20.892	21.346
Coeff. of barley		81.0	83.8	76.9	15.9	22.9	90.2	84.9
Animal No. 4								
In hay	54.000	46.937	44.712	0.557	0.840	18.620	21.769	40.389
In oats	36.000	30.960	29.917	0.597	0.542	4.316	21.582	25.898
In total ration	90.000	77.897	74.629	1.154	1.382	22.936	43.351	66.287
In feces	143.088	34.290	31.852	0.444	0.624	13.387	15.242	28.629
Digested		43.607	42.777	0.710	0.758	9.549	28.109	37.658
Dig. from hay		22.671	22.177	0.243	0.365	9.012	11.276	20.288
Dig. from oats		20.936	20.600	0.467	0.393	0.537	16.833	17.370
Coeff. of oats		67.6	68.9	78.2	72.5	12.4	78.0	67.1
Animal No. 5								
In hay	54.000	46.937	44.712	0.557	0.840	18.620	21.769	40.389
In barley	12.000	10.128	9.792	0.225	0.096	0.661	7.724	8.385
In oats	12.048	10.361	10.012	0.200	0.181	1.444	7.223	8.667
In oil cake	12.093	11.090	10.433	0.628	1.202	0.995	4.907	5.902
In total grain	36.141	31.579	30.237	1.053	1.479	3.100	19.854	22.954
In total ration	90.141	78.516	74.949	1.610	2.319	21.720	41.623	63.343
In feces	152.108	32.143	29.433	0.534	0.617	12.295	13.400	25.695
Digested		46.373	45.516	1.076	1.702	9.425	28.223	37.648
Dig. from hay		22.671	22.177	0.243	0.365	9.012	11.276	20.288
Dig. from grain		23.702	23.339	0.833	1.337	0.413	16.947	17.360
Coeff. of grain		75.1	77.2	79.1	90.4	13.3	85.4	75.6
Animal No. 6								
In hay	80.500	69.971						
Refused	0.310	0.255						
Consumed		69.716	66.411	0.828	1.248	27.656	32.334	59.990
In feces	143.448	34.645	32.161	0.458	0.683	13.612	14.915	28.527
Digested		35.071	34.250	0.370	0.565	14.044	17.419	31.463
Coefficient		50.3	51.6	44.7	45.3	50.8	53.9	52.4

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PER CENT.)—*Continued*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
PERIOD 4								
Animal No. 2								
In hay	54.000	47.153	44.960	0.550	0.835	18.786	21.903	40.689
In barley	12.000	10.112	9.772	0.225	0.054	0.683	7.726	8.409
In oats	12.051	10.345	9.965	0.202	0.158	1.515	7.116	8.631
In oil cake	12.056	11.073	10.420	0.612	1.218	0.971	4.986	5.957
In total grain	36.107	31.530	30.157	1.039	1.430	3.169	19.828	22.997
Total ration	90.107	78.683	75.117	1.589	2.265	21.955	41.731	63.686
In feces	153.739	32.642	29.880	0.514	0.571	12.672	13.631	26.303
Digested		46.041	45.237	1.075	1.694	9.283	28.100	37.383
Dig. from hay		22.775	22.300	0.240	0.363	9.092	11.346	20.438
Dig. from grain		23.266	22.937	0.835	1.331	0.191	16.754	16.945
Coeff. of grain		73.8	76.1	80.4	93.1	6.0	84.5	73.7
Animal No. 3								
In hay	54.000	47.153	44.960	0.550	0.835	18.786	21.903	40.689
In oats	36.000	30.902	29.768	0.603	0.473	4.524	21.257	25.781
Total	90.000	78.055	74.728	1.153	1.308	23.310	43.160	66.470
In feces	145.560	34.713	31.932	0.464	0.587	13.201	15.433	28.634
Digested		43.342	42.796	0.689	0.721	10.109	27.727	37.836
Dig. from hay		22.775	22.300	0.240	0.363	9.092	11.346	20.438
Dig. from oats		20.567	20.496	0.449	0.358	1.017	16.381	17.398
Coeff. of oats		66.6	68.9	74.5	75.7	22.5	77.1	67.5
Animal No. 4								
In hay	54.000	47.153	44.960	0.550	0.835	18.786	21.903	40.689
In barley	18.000	15.169	14.659	0.337	0.080	1.024	11.589	12.613
In oats	18.078	15.518	14.948	0.303	0.237	2.272	10.675	12.947
In total grain	36.078	30.687	29.607	0.640	0.317	3.296	22.264	25.560
Total ration	90.078	77.840	74.567	1.190	1.152	22.082	44.167	66.249
In feces	159.635	33.192	30.573	0.500	0.627	12.537	14.455	26.992
Digested		44.648	43.994	0.690	0.525	9.545	29.712	39.257
Dig. from hay		22.775	22.300	0.240	0.363	9.092	11.346	20.438
Dig. from grain		21.873	21.694	0.450	0.162	0.453	18.366	18.819
Coeff. of grain		71.3	73.3	70.3	51.1	13.7	82.5	73.6
Animal No. 5								
In hay	54.000	47.153	44.960	0.550	0.835	18.786	21.903	40.689
In barley	36.000	30.337	29.318	0.674	0.161	2.048	23.177	25.225
In total ration	90.000	77.490	74.278	1.224	0.996	20.834	45.080	65.914
In feces	150.671	31.354	28.959	0.499	0.599	12.225	13.253	25.478
Digested		46.136	45.319	0.725	0.397	8.609	31.827	40.436
Dig. from hay		22.775	22.300	0.240	0.363	9.092	11.346	20.438
Dig. from barley		23.361	23.019	0.485	0.034	−0.483	20.481	19.998
Coeff. of barley		77.0	78.5	72.0	21.1	−23.6	88.4	79.3
Animal No. 6								
In hay	54.000	47.153	44.960	0.550	0.835	18.786	21.903	40.689
In oil cake	36.000	33.066	31.115	1.828	3.637	2.900	14.890	17.790
In total ration	90.000	80.219	76.075	2.378	4.472	21.686	36.793	58.479
In feces	141.328	32.892	29.771	0.611	0.632	12.295	13.088	25.383
Digested		47.327	46.304	1.767	3.840	9.391	23.705	33.096
Dig. from hay		22.775	22.300	0.240	0.363	9.092	11.346	20.438
Dig. from oil cake		24.552	24.004	1.527	3.477	0.299	12.359	12.658
Coeff. of oil cake		74.3	77.1	83.5	95.6	10.3	83.0	71.2
Animal No. 7								
In hay	60.000	52.524	49.924	0.688	0.987	21.025	23.610	44.635
In feces	124.485	27.832	25.828	0.355	0.573	11.133	11.934	23.067
Digested		24.692	24.096	0.333	0.414	9.892	11.676	21.568
Coefficient		47.0	48.3	48.4	41.9	47.0	49.5	48.3

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PER CENT.)—*Continued*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
PERIOD 5								
Animal No. 1								
In hay	54.000	46.877	43.839	0.571	1.186	16.838	22.248	39.086
In barley	18.000	15.232	14.740	0.338	0.120	1.022	11.628	12.650
In oats	18.148	15.582	15.074	0.310	0.394	2.023	10.851	12.874
In total grain	36.148	30.814	29.814	0.648	0.514	3.045	22.479	25.524
In total ration	90.148	77.691	73.653	1.219	1.700	19.883	44.727	64.610
In feces	180.663	31.509	28.576	0.479	0.725	11.227	14.025	25.252
Digested		46.182	45.077	0.740	0.975	8.656	30.702	39.358
Dig. from hay		25.407	24.374	0.278	0.614	9.093	12.948	22.041
Dig. from grain		20.775	20.703	0.462	0.361	−0.437	17.754	17.317
Coeff. of grain		67.4	69.4	71.3	70.2	−14.4	79.0	67.8
Animal No. 2								
In hay	54.000	46.877	43.839	0.571	1.186	16.838	22.248	39.086
In barley	36.000	30.463	29.479	0.676	0.241	2.044	23.255	25.299
In total ration	90.000	77.340	73.318	1.247	1.427	18.882	45.503	64.385
In feces	140.271	28.788	25.958	0.459	0.766	10.251	12.241	22.492
Digested		48.552	47.360	0.788	0.661	8.631	33.262	41.893
Dig. from hay		25.407	24.374	0.278	0.614	9.093	12.948	22.041
Dig. from barley		23.145	22.986	0.510	0.047	−0.462	20.314	19.852
Coeff. of barley		76.0	78.0	75.4	19.5	−22.6	87.4	78.5
Animal No. 3								
In hay	54.000	46.877	43.839	0.571	1.186	16.838	22.248	39.086
In barley	12.000	10.154	9.826	0.225	0.080	0.681	7.752	8.433
In oats	12.099	10.388	10.049	0.207	0.263	1.348	7.234	8.582
In oil cake	12.181	11.119	10.477	0.620	1.243	0.942	5.006	5.948
In total grain	36.280	31.661	30.352	1.052	1.586	2.971	19.992	22.963
In total ration	90.280	78.538	74.191	1.623	2.772	19.809	42.240	62.049
In feces	148.701	30.223	27.074	0.497	0.780	10.557	12.660	23.217
Digested		48.315	47.117	1.126	1.992	9.252	29.580	38.832
Dig. from hay		25.407	24.374	0.278	0.614	9.093	12.948	22.041
Dig. from grain		22.908	22.743	0.848	1.378	0.159	16.632	16.791
Coeff. of grain		72.4	74.9	80.6	86.9	5.4	83.2	73.1
Animal No. 4								
In hay	54.000	46.877	43.839	0.571	1.186	16.838	22.248	39.086
In oil cake	36.000	32.861	30.965	1.833	3.674	2.783	14.794	17.577
In total ration	90.000	79.738	74.804	2.404	4.860	19.621	37.042	56.663
In feces	158.138	30.822	27.472	0.581	0.798	10.988	12.156	23.144
Digested		48.916	47.332	1.823	4.062	8.633	24.886	33.519
Dig. from hay		25.407	24.374	0.278	0.614	9.093	12.948	22.041
Dig. from oil cake		23.509	22.958	1.545	3.448	−0.460	11.938	11.478
Coeff. of oil cake		71.5	74.1	84.3	93.8	−16.5	80.7	65.3
Animal No. 5								
In hay	71.000	61.997	59.114	0.723	1.097	24.700	28.798	53.498
Refused	0.229	0.207	0.157	0.004	0.004	0.053	0.078	0.131
Consumed	70.771	61.790	58.957	0.719	1.093	24.647	28.720	53.367
In feces	176.490	31.127	28.780	0.454	0.644	12.174	13.238	25.412
Digested		30.663	30.177	0.265	0.449	12.473	15.482	27.955
Coefficient		49.6	51.2	36.9	41.1	50.6	53.9	52.4
Animal No. 6								
In hay	54.000	46.877	43.839	0.571	1.186	16.838	22.248	39.086
In barley	18.000	15.232	14.740	0.338	0.120	1.022	11.628	12.650
In oats	18.148	15.582	15.074	0.310	0.394	2.023	10.851	12.874
In total grain	36.148	30.814	29.814	0.648	0.514	3.045	22.479	25.524
In total ration	90.148	77.691	73.653	1.219	1.700	19.883	44.727	64.610
In feces	131.111	29.489	26.522	0.452	0.781	10.068	13.061	23.129
Digested		48.202	47.131	0.767	0.919	9.815	31.666	41.481
Dig. from hay		25.407	24.374	0.278	0.614	9.093	12.948	22.041
Dig. from grain		22.795	22.757	0.489	0.305	0.722	18.718	19.440
Coeff. of grain		74.0	76.3	75.5	59.3	23.7	83.3	76.2

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PERCENT.)—*Continued*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
Period 5—*Conc.*								
Animal No. 7								
In hay	48.000	41.669	38.969	0.508	1.054	14.968	19.776	34.744
In oats	30.000	25.758	24.918	0.512	0.652	3.343	17.938	21.281
In total ration	78.000	67.427	63.887	1.020	1.706	18.311	37.714	56.025
In feces	124.718	28.320	25.737	0.391	0.705	9.932	12.843	22.775
Digested		39.107	38.150	0.629	1.001	8.379	24.871	33.250
Dig. from hay		22.585	21.667	0.247	0.546	8.083	11.510	19.593
Dig. from oats		16.522	16.483	0.382	0.455	0.296	13.361	13.657
Coeff. of oats		64.1	66.1	74.6	69.8	8.9	74.5	64.2
PERIOD 6								
Animal No. 1								
In hay	54.000	47.428	44.250	0.535	1.318	17.122	22.467	39.589
In barley	12.000	10.184	9.864	0.223	0.080	0.673	7.811	8.484
In oats	12.107	10.418	10.078	0.198	0.372	1.428	7.122	8.550
In oil cake	12.200	11.151	10.490	0.622	1.190	0.960	5.041	6.001
In total grain	36.307	31.753	30.432	1.043	1.642	3.061	19.974	23.035
In total ration	90.307	79.181	74.682	1.578	2.960	20.183	42.441	62.624
In feces	178.176	30.615	27.382	0.508	0.876	10.565	13.014	23.579
Digested		48.566	47.300	1.070	2.084	9.618	29.427	39.045
Dig. from hay		25.706	24.603	0.260	0.683	9.246	13.076	22.322
Dig. from grain		22.860	22.697	0.810	1.401	0.372	16.351	16.723
Coeff. of grain		72.0	74.6	77.7	85.3	12.2	81.9	72.6
Animal No. 2								
In hay	54.000	47.428	44.250	0.535	1.318	17.122	22.467	39.589
In oats	36.000	30.978	29.968	0.590	1.106	4.247	21.177	25.424
In total ration	90.000	78.406	74.218	1.125	2.424	21.369	43.644	65.013
In feces	145.930	33.065	30.119	0.432	0.777	12.208	14.730	26.938
Digested		45.341	44.099	0.693	1.647	9.161	28.914	38.075
Dig. from hay		25.706	24.603	0.260	0.683	9.246	13.076	22.322
Dig from oats		19.635	19.496	0.433	0.964	−0.085	15.838	15.753
Coeff. of oats		63.4	65.1	73.4	87.2	−2.0	74.8	62.0
Animal No. 3								
In hay	54.000	47.428	44.250	0.535	1.318	17.122	22.467	39.589
In barley	18.000	15.277	14.797	0.334	0.121	1.010	11.717	12.727
In oats	18.162	15.628	15.119	0.298	0.558	2.143	10.683	12.826
In total grain	36.162	30.905	29.916	0.632	0.679	3.153	22.400	25.553
In total ration	90.162	78.333	74.166	1.167	1.997	20.275	44.867	65.142
In feces	146.361	31.413	28.404	0.446	0.807	11.328	13.674	25.002
Digested		46.920	45.762	0.721	1.190	8.947	31.193	40.140
Dig. from hay		25.706	24.603	0.260	0.683	9.246	13.076	22.322
Dig. from grain		21.214	21.159	0.461	0.507	−0.299	18.117	17.818
Coeff. of grain		68.6	70.7	72.9	74.7	−9.5	80.9	69.7
Animal No. 4								
In hay	84.000	73.777	68.834	0.832	2.051	26.633	34.948	61.581
In feces	177.290	33.634	30.540	0.417	0.969	12.626	14.496	27.122
Digested		40.143	38.294	0.415	1.082	14.007	20.452	34.459
Coefficient		54.4	55.6	49.9	52.8	52.6	58.5	56.0
Animal No. 5								
In hay	54.000	47.428	44.250	0.535	1.318	17.122	22.467	39.589
In oil cake	36.000	32.904	30.953	1.836	3.511	2.833	14.876	17.709
In total ration	90.000	80.332	75.203	2.371	4.829	19.955	37.343	57.298
In feces	155.525	31.993	28.371	0.587	0.781	11.473	12.736	24.209
Digested		48.339	46.832	1.784	4.048	8.482	24.607	33.089
Dig. from hay		25.706	24.603	0.260	0.683	9.246	13.076	22.322
Dig. from oil cake		22.633	22.229	1.524	3.365	−0.764	11.531	10.767
Coeff. of oil cake		68.8	71.8	83.0	95.8	−27.0	77.5	60.8

TABLE 7.—CALCULATION OF COEFFICIENTS OF DIGESTIBILITY. (COLLECTION PERIOD OF 12 DAYS; WEIGHTS IN KILOGRAMMES; COEFFICIENTS IN PERCENT.)—*Concluded*

—	Original weights	Dry matter	Organic matter	Nitrogen	Ether extract	Crude fibre	N-free extract	Carbo-hydrates
Period 6—*Conc.*								
Animal No. 6								
In hay	54.000	47.428	44.250	0.535	1.318	17.122	22.467	39.589
In barley	12.000	10.184	9.864	0.223	0.080	0.673	7.811	8.484
In oats	12.107	10.418	10.078	0.198	0.372	1.428	7.122	8.550
In oil cake	12.200	11.151	10.490	0.622	1.190	0.960	5.041	6.001
In total grain	36.307	31.753	30.432	1.043	1.642	3.061	19.974	23.035
In total ration	90.307	79.181	74.682	1.578	2.960	20.183	42.441	62.624
In feces	143.767	31.346	28.193	0.485	0.733	11.300	13.297	24.597
Digested		47.835	46.489	1.093	2.227	8.883	29.144	38.027
Dig. from hay		25.706	24.603	0.260	0.683	9.246	13.076	22.322
Dig. from grain		22.129	21.886	0.833	1.544	−0.363	16.068	15.705
Coeff. of grain		69.7	71.9	79.9	94.0	−11.9	80.4	68.2
Animal No. 7								
In hay	48.000	42.158	39.333	0.476	1.172	15.219	19.970	35.189
In barley	30.000	25.461	24.662	0.557	0.201	1.683	19.529	21.212
In total ration	78.000	67.619	63.995	1.033	1.373	16.902	39.499	56.401
In feces	114.866	25.862	23.325	0.388	0.667	9.251	11.196	20.447
Digested		41.757	40.670	0.645	0.706	7.651	28.303	35.954
Dig. from hay		22.850	21.869	0.231	0.607	8.218	11.623	19.841
Dig. from barley		18.907	18.801	0.414	0.099	−0.567	16.680	16.113
Coeff. of barley		74.3	76.2	74.3	49.3	−33.7	85.4	76.0
PERIOD 7								
Animal No. 1								
In hay	84.000	74.432	69.549	0.782	1.950	27.071	35.645	62.716
In feces	207.263	34.882	31.478	0.428	0.942	12.571	15.223	27.794
Digested		39.550	38.071	0.354	1.008	14.500	20.422	34.922
Coefficient		53.1	54.7	45.3	51.7	53.6	57.3	55.7
Animal No. 2								
In hay	54.000	47.849	44.710	0.503	1.254	17.403	22.915	40.318
In barley	18.000	15.269	14.793	0.345	0.118	0.850	11.815	12.665
In oats	18.029	15.620	15.115	0.299	0.622	2.156	10.593	12.749
In total grain	36.029	30.889	29.908	0.644	0.740	3.006	22.408	25.414
In total ration	90.029	78.738	74.618	1.147	1.994	20.409	45.323	65.732
In feces	146.510	31.381	28.375	0.427	0.810	11.106	13.889	24.995
Digested		47.357	46.243	0.720	1.184	9.303	31.434	40.737
Dig. from hay		25.934	24.859	0.244	0.650	9.398	13.337	22.735
Dig. from grain		21.423	21.384	0.476	0.534	−0.095	18.097	18.002
Coeff. of grain		69.4	71.5	73.9	72.2	−3.2	80.8	70.8
Animal No. 3								
In hay	54.000	47.849	44.710	0.503	1.254	17.403	22.915	40.318
In oil cake	36.000	33.037	31.042	1.831	3.234	3.224	14.877	18.101
In total ration	90.000	80.886	75.752	2.334	4.488	20.627	37.792	58.419
In feces	164.484	31.345	27.750	0.556	0.849	10.950	12.619	23.569
Digested		49.541	48.002	1.778	3.639	9.677	25.173	34.850
Dig. from hay		25.934	24.859	0.244	0.650	9.398	13.337	22.735
Dig. from oil cake		23.607	23.143	1.534	2.989	0.279	11.836	12.115
Coeff. of oil cake		71.5	74.6	83.8	92.4	8.7	79.6	66.9
Animal No. 4								
In hay	84.000	74.432	69.549	0.782	1.950	27.071	35.645	62.716
In feces	164.604	33.450	30.155	0.386	0.960	11.985	14.691	26.676
Digested		40.982	39.394	0.396	0.990	15.086	20.954	36.040
Coefficient		55.1	56.6	50.6	50.8	55.7	58.8	57.5

BOOK REVIEWS

MacEwan, J. W. G. and A. H. Ewen: General Agriculture: 345 pages. Published by Thomas Nelson and Sons, Limited, Toronto, 1939.

This book on "General Agriculture" is another by the authors of "The Science and Practise of Canadian Animal Husbandry" which was published in 1936. General Agriculture brings together a large number of useful and interesting facts pertaining to many phases of agriculture. As the title implies, the subject matter deals with general agriculture and reference to the fundamental sciences is used only to clarify certain portions of the text. The book has been prepared to facilitate effective study and develop a better understanding of the internationally important basic industry—Agriculture.

The book is divided into three parts—part one, the soil; part two, plants, and part three, animals. Two chapters are included in part one, the first dealing with various fundamental principles concerning the soil itself. These include: soil weathering and classification, chemical and physical constituents in the soil as related to plant growth, soil fertility and fertilizers, soil survey, wind and water erosion, drainage and irrigation. Chapter two has to do with tillage machinery and methods of soil cultivation. A very complete description is given of the various types of ploughs, cultivators and seeding machinery in common use and reference is made to the purpose for which each is used and the methods employed in their operation.

In part two, twelve chapters deal with various aspects of the plant world. Reference is made to the importance of plants, their structure, methods of improvement by breeding, selection and vegetative reproduction. Three chapters deal with various cereal, hay, pasture, silage, root, and tuber crops. Information is given in connection with each of the commonly grown agricultural crops under the headings of history of the plant, structure, distribution, cultural methods, grades and varieties. The summerfallow, strip farming, row crops and cropping systems are discussed under the heading of "Crop rotations and cropping systems." A considerable fund of information is given in relation to the growing and handling of horticultural crops with one chapter devoted to fruit plants and one to gardening with all its intricacies and details.

As applied to all of these crops, selection and preparation of seed has reference to germination of seed, seed regulations, elite and registered seed and seed judging. A chapter is devoted to methods of haying and harvesting with various types of machinery.

A very fitting conclusion to this section concerning plants is three chapters dealing with weeds and their eradication, plant diseases and their control and insects affecting plants and methods for their destruction. In the entire section on plants the authors have presented the fundamentals of plant culture in a clear and concise manner and where a diversity of methods exists, as often does between the agriculture of eastern and western Canada, these have been very nicely disposed of by a brief reference to the difference in methods.

In part three, one hundred and thirty-four pages are devoted to information on farm animals. A chapter dealing with domestication and improvement outlines type characteristics of various animals with suggestions in regard to points to be considered in judging. This is followed by notes in regard to all of the common breeds of farm animals with reference to their origination, use and general characteristics. The nutrition of farm animals is covered under such headings as water, fats, proteins, carbohydrates, mineral matter, vitamins, the digestive system, digestibility of feeds, nutritive ratio, feeding standards, and concludes with a section describing various feeds, their uses, methods of preparation and amounts to feed to various species of animals.

Parasites affecting live stock are referred to briefly and five chapters are devoted to feeding and management of the five main species of farm animals, dairy cattle, beef cattle, sheep, pigs and horses. To complete the picture in regard to general agriculture, the final chapter is devoted to a description of various species of poultry with suggestions in regard to breeding, hatching, feeding and raising.

In the preparation of this book the needs of young people have been kept foremost in the minds of the authors, but the text should also be of great value to teachers of agriculture in schools, to farmers generally, and to anyone desiring a ready reference to a wide variety of agricultural subjects. The book is well indexed and contains a list of texts and references as a source of more specific information.

P. O. Ripley.

Winters, Lawrence M. Animal Breeding (Third Edition). John Wiley & Sons, Inc.

The science of genetics is continually contributing new and fundamental knowledge associated with the improvement and development of domestic animals. With this in mind, the recent and third edition of "Animal Breeding" by Professor Winters will be welcomed by all those whose interests lie in this field as its main purpose is to present and interpret the more recent and accepted information related to this subject.

A number of new chapters have been included, making a timely addition to the literature now available on some of the recent developments. The chapter devoted to artificial insemination, while not dealing exhaustively with the subject, offers useful information in connection with the technique involved in artificial insemination—a subject of almost world wide interest at present. The chapter on Lethals is of special interest in that it is discussed in relation to the various defects and abnormalities not uncommonly met with in live stock breeding. Something new, based on Professor Winters' investigation, is reviewed under the heading "Fertilization and Pre-Natal Development." This embodies a number of illustrations depicting the various stages of pre-natal development in sheep.

The section covering reproduction has been enlarged to include a discussion of the endocrene glands and the influence of hormones as affecting the various bodily functions concerned with embriological development as well as lactation. In the final chapter—"Looking Forward," the author mentions and discusses a number of mediums through which an animal

breeding programme may be strengthened. Among these are included record of performance, use of outstanding sires, artificial insemination, development of pure lines, regional breeding laboratories and the purebred breeder.

As would be expected in a text on animal breeding, proper emphasis has been placed on those subjects connected with the more specific fields such as the fundamental laws of heredity, the mechanism and physiology of reproduction, the Mendelian basis of inheritance, together with the various systems of breeding, all discussed in the light of modern information.

As was the case with the two previous editions, a quite complete bibliography has been presented which affords an opportunity for a complete review of the pertinent literature.

J. P. Sackville.